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The Isthmian Canal.

The President submitted to Congress on Monday the long-awaited report of the Board of Consulting Engineers, together with the report of the Isthmian Canal Commission, a letter from the Secretary of War, a statement by the Chief Engineer of the Commission, and a letter from himself commenting upon these papers and recommending an 85-ft. summit level canal with six locks across the Isthmus of Panama. The letter of the President, printed in the Current News Supplement, is, on the whole, most surprising and scarcely less disappointing. It is surprising because in his remarks to the Board of Consulting Engineers at Oyster Bay last September he used the following language: "I have named you because in my judgment you are especially fit to serve as advisors in planning the greatest engineering work the world has yet seen; . . . I hope that ultimately it will prove possible to build a sea-level canal. Such a canal would undoubtedly be best in the end if feasible; and I feel that one of the chief advantages of the Panama route is that ultimately a sea-level canal will be a possibility . . ." and more of the same import. If the members of the Consulting Board, representing both American and European experience and judgment, were indeed so eminently qualified to pass upon the merits of this great work, it is surprising that the unqualified judgment of a substantial majority should be disregarded for reasons which scarcely appear convincing.

This journal appreciates deeply the grave responsibilities resting on the President and the Secretary of War in connection with this great work, and the following observations are made with full consideration for the magnitude of the many diverse interests entrusted to the President and occupying his time. It seems peculiarly unfortunate, however, that the line between the foreign and American engineers should have been so distinctly drawn in his letter. It is not too much to say that the fact of five out of eight of the majority of the Consulting Board being foreign engineers appears to destroy the weight of their judgment in the view of the President. If the judgment of these eminent engineers was to be undermined by their foreign nationality, the question cannot fail to arise why their services were sought in this matter. The American people desire a clear, unprejudiced and comprehensive consideration of the plan of the Isthmian Canal to be adopted and it matters little, indeed none at all, whether the best solution of the question is reached through the judgment of foreign or American engineers, or, better still, through that of both. It is a serious matter at the most important juncture of this serious business to find the recommendation of the highest official in the government apparently affected to the slightest degree by what may be termed international prejudice. Again, it is not illuminating, to say the least, to cite various combinations of membership of the Consulting Board and Commission to show that a majority of the American engineers are in favor of one type or another. If that class of argument is to be prominently used to justify the ultimate selection, it should have been stated that there are but four engineer members of the present Commission, who, with the thirteen of the Consulting Board, make a total of seventeen engineers, with nine out of that seventeen in favor of the sea-level plan. It is, therefore, a fact that a majority of that portion of the combined membership of the Consulting Board and Commission really qualified to pass a technical judgment at all upon this great question advocate the sea-level plan. The former Commission, one of the best ever organized for a great undertaking, was in favor of a sea-level canal, and so was its chief engineer, Mr. John F. Wallace.

Leaving these less material features of the President's letter of transmission, it is the present purpose of The Engineering Record to consider those matters which have a more direct and satisfactory bearing on the solution of this great engineering question. In subsequent issues full editorial comment will be made upon the majority and minority reports. In this issue only those general features which are likely to form initial impressions as they are set forth before the public will be considered, leaving the larger technical details for later treatment. A full abstract of the report of the Board of Advisory Engineers is printed elsewhere in this issue, and the recommendations of the minority of its members are outlined below in order that the reader may have all the facts before him.

The minority of the members of the Board of Consulting Engineers recommended a project with the summit level at El. 85, being essentially a modification of the plan of the Isthmian Canal Commission of 1889-91. The locks have a usable length of 900 ft. and a usable width of 95 ft. The controlling feature is an extraordinary earth dam across the Chagres at Gatun, forming a reservoir to impound the waters of that stream and serve as a part of the summit level of the canal. This dam is really a great dike, with its top 50 ft. above the water level and 100 ft. wide; at the water level the thickness is 374 ft. The downstream toe for about 200 ft. is to be built of rock, so that any seepage will find no material that can be washed away. The lower part of the structure is to be built of material dredged from the canal between the Gatun locks and Limon Bay and pumped into the dam. It is expected that for the upper part of the dam spoil from the Culebra cut can be used. The cross-section of the dam shown on page 217 gives some idea of its enormous size. No attempt will be made to prevent the percolation of water below the structure, as it is considered by the minority of the Board that such a thing is wholly improbable. The regulating works consist of Stoney sluices, capable of discharging 140,000 cu. ft. per second; their general arrangement is illustrated on page 216.

The summit level will be reached from the Atlantic side by duplicate flights of three locks at Gatun, and the total length of Lake Gatun will be 30 miles, of which 23 miles will be navigated by ships crossing the Isthmus. It will be continued by an excavated channel to duplicate locks of a single 31-ft. lift at Pedro Miguel, a short distance from Paraiso. For a distance of 4.7 miles through the deep portion of the Culebra cut the channel is to have a bottom width of 200 ft. and nearly vertical sides below the water line. The minority of the Board states that the waterway from Gatun to Culebra resembles that of the St. Mary's River, being nowhere less than 300 ft. wide.

Passing the Pedro Miguel locks the channel will be 500 ft. wide for 1.64 miles and then increase to 1,000 ft. or more for a further distance of 3.38 miles to the Sosa locks on the shore of Panama Bay. These will be duplicate locks having two lifts of about 31 ft. each. This level will be formed by dams at La Boca, between Sosa and Ancon Hills and from Ancon Hill in the direction of Corozal to high land across the present line of the railroad. These structures will be of the same type as that at Gatun, and their cross-sections are shown on page 217. The waterway formed by them is termed Lake Sosa.

The total length of the canal formed in this way is 49.72 miles, of which 19.08 miles has a width of 1,000 ft. or more, 3.86 miles one of 800 ft., 12.29 miles one of 500 ft., 7.21 miles one of 300 ft., 4.70 miles one of 200 ft., and 2.58 miles consist of the locks and their approaches. The sea-level section on the Atlantic side will have a depth of not less than 40 ft. at all tides. In the summit level the depth will be 42 ft. or more at extreme low water and 45 ft. or more under usual conditions. From Pedro Miguel to Sosa the depth will be 45 ft. or more, and in Panama Bay 45 ft. below mean tide. The total cost of the project is estimated by the minority of the Board at $140,000,000.

In the statements, largely in the nature of instructions, made to the Consulting Board by the President in September last he laid down the principle, which appears to be one of wisdom, that if a lock plan of canal should be adopted it should be such that the resulting canal can subsequently be reduced to a sea-level waterway with the least expenditure of money and time. This position seems now to be entirely abandoned. The recommended type of canal practically does not admit of such transformation. Indeed, in the report of the Consulting Board, it appears to be the unanimous judgment that the difficulties in the way of transformation of the recommended type are such as to put that transformation out of the question. In other words, the recommended plan is of such a character as to make the ultimate attainment of a sea-level canal essentially an impossibility. A reflective observer of this whole subject cannot fail to wonder what has induced the President to change his position so radically in regard to this work.

There seems to be some erroneous public impressions in regard to this particular aspect of the recommended plan. One of the great morning dailies of New York, "The Sun," in an editorial comment on the matter, has expressed great satisfaction in the fact that both the Secretary of War and the President emphasized in their communications the feature of transformation of the recommended plan, whereas the lock plan places transformation to a sea-level canal out of consideration.

A careful reading of the President's letter of transmission discloses a number of other features which scarcely bear close examination, but ought to be analyzed carefully in order to give the public a clear and adequate conception of those portions of this great work to which they apply. It is stated that the judgment of the five foreign engineers is partly to be explained by the fact that the Suez Canal is a sea-level canal, whereas the great traffic canal of America, the lock canal at Sault Ste. Marie, disregarding for the moment the actual fact that the waterway at this place is scarcely a canal at all, but a lock with very short approaches. It is well to bear in mind that only one of the five foreign members of the Consulting Board has had any experience either with the Suez Canal or any other sea-level canal, but that three of the five have had many years' experience in the construction and operation of great lock canals. It is fair to assume that their experience with those canals was such as to induce them to believe that the lock feature should be omitted wherever it is practicable to do without it.

Much weight is attached both by the minority of the Consulting Board and by the President and Secretary of War to the fact that the Soo lock is capable of passing a great traffic in the course of a short season which does not include the winter months. As most forcibly pointed out in the report of the majority of the Board, this fact can be very easily misinterpreted. The administration of the Soo lock is certainly characterized by a remarkably high degree of efficiency, but if one should accept at the face value the enthusiastic observations of the minority report, which have apparently greatly influenced the President, one might almost conclude that the high degree of efficiency is due to the presence of the lock and that no one would desire an open unrestricted channel at that point. As a matter of fact, ever since the traffic through the Soo has been of sensible magnitude there has been a perpetual reconstruction of existing locks into those of much greater capacity. There is about to be another repetition in the same series, as it is the intention of the government to construct another lock of more than 50 per cent. greater capacity than the Poe lock, which now carries the great bulk of the traffic. These locks, therefore, have continually been found to be of such restricting character that their constant rebuilding into greatly enlarged structures has been the continuous history of the Sault Ste. Marie canal.

The natural query that arises in connection with the recommended plan of the Panama Canal is whether, after its completion with the relatively small locks remommended, 900x95 ft., perpetual reconstruction of those locks will be required for all time, and if so, what will be the ultimate cost and what will be the method of procedure. In view of all the experiences with large canal locks, both in Europe and in this country, one can scarcely credit as being serious the statement that a lock canal, with all the grave dangers of lockage in series to which great ocean steamships must subject themselves in passing across the Isthmus, exhibits "superior safety, feasibility and desirability" in the construction and operation of a great ship waterway.

As has often been stated in its columns, The Engineering Record has no partisan feeling in this Isthmian Canal business, but it desires that the great ship waterway to be constructed by the United States government, not for one generation or two or for the present administration or for any other, but for all time, should be of such a type as to serve best the interests of the country and of the great ocean traffic it is destined to carry. After having submitted the entire question to the prolonged study of a Board of Consulting Engineers second to none ever convened in experience, in fairness and in engineering ability, it believes that the verdict of such a body should be followed and that a sea-level canal should be constructed across the Isthmus of Panama.

The present situation is well nigh hopelessly confused and obscured. There never has been a juncture in the life of this enterprise when more deliberate judgment, more careful procedure in the examination of the project before Congress, or more thoughtful reflection should be given to it, than at the present time. It is earnestly to be hoped that both houses of Congress will not be moved by the impulse of the moment, which may be raised in favor of what cannot fail to be recognized in cooler moments as a makeshift involving more time and money than appear in the estimates, and will reach a conclusion that will be justified by the experience of future years. There should be no haste in the Senate particularly, where there is a better opportunity to regard most carefully all the conditions of this great enterprise, for there is grave danger at the present time of committing a colossal national error almost impossible to rectify.

A Long Step Forward in Municipal Water Supplies.

This journal takes more pleasure in presenting the description of the water softening and filtering works at Columbus, printed in this issue, than in any article on water purification which it has published for a long time. A study of the explanation of the processes and works at Columbus will show that the advance in water-works engineering which they represent is greater than anything since the experiments at Louisville, made by Mr. George W. Fuller for Mr. Charles Hermany; the Louisville investigations established the value of rapid filtration, while the Columbus investigations show that hardness can be overcome without difficulty. The former experiments brought about a great change in the design of works for filtration, and it is safe to say that Columbus will set a new example to cities and industrial establishments suffering the inconveniences that attend the use of hard water. Another reason for the gratification experienced in presenting this description is the positive proof it affords of the close relation between scientific research and progress in engineering practice. The contaminating and hardening matter in water is of such a trifling quantity compared with the volume of the liquid itself that a good many people who watch operations in a chemical laboratory are led to wonder if the results are worth the expense of these scientific investigations. The actual amounts of the polluting matter, the carbonates and sulphates, are so insignificant that the lay mind is likely to consider them negligible. Yet it is safe to say that the investigation of these infinitesimals at Columbus will save the citizens of that place a very great sum annually; it will not only result in a thoroughly safe water supply hygienically but also one which will be satisfactory to the industries of the city.

The history of the undertaking is interesting. Scarcity of water forced the city to look beyond its present sources for an additional supply. A number of investigations were made which showed that the Scioto River was the best place to go, but the water not only needs filtration but also softening. The supply was ample, the cost of developing it reasonable, and the only question to be settled was about its character. It was soon determined that it could be filtered so as to be unquestionably good hygienically, but its hardness was a matter of perplexity. A hard water is not so good as a soft water for domestic purposes, while it is the bane of industries. In fact, it is so essential to have soft water for many manufacturing purposes that industrial softening plants of numerous patented types are on the market. The softening of such a great supply as that required at Columbus was a novel proposition, however, and the Board of Public Service very wisely agreed with its engineer, Mr. Julian Griggs, that the matter was one demanding the assistance of expert advisers. Accordingly Messrs. Rudolph Hering and George W. Fuller were retained to report on the subject and to supervise the planning of works for the purification of the supply. Fortunately the Board had its own experimental laboratory engaged on a study of the methods of purifying the sewage of the city, and it was thus able to carry on, with the assistance of the best corps of analysts ever brought together on such a problem in this country, a careful study of the special characteristics of the Scioto river water and the methods of treating it. As a result of these studies, it was found to be entirely practicable to remove not only the temporary hardness due to carbonates but also the permanent hardness due to sulphates. It was also found that in the softening process a large amount of hydrate of magnesia would be formed. This is a gelatinous substance useful as a coagulant, and by taking advantage of it the rapid filtration of the softened water will probably be carried on for months at a time without any necessity for special coagulants. This fact in itself shows the value of thorough research work in a problem of this nature.

In this way the basic facts on which the softening and filtration depend were established, and the design of the works for the purpose could be taken up. Here again, the Board of Public Service and Mr. Griggs showed their full appreciation of the gravity of the problem in their charge. They brought to the city a corps of experienced engineers in such design, who have planned a system of works which is so flexible in its operating character that every contingency is provided for. The design of such works is a specialty, and an examination of the plans published elsewhere in this issue will show the Board's wisdom in intrusting it to specialists. This journal has no hesitation in saying that the plans and specifications for this undertaking have been worked out with a completeness and accuracy that make them models of their kind.

The work done so far has been of such a high order that it is to be hoped the Board will continue the same policy in the construction and operation of the plant. A great deal of its success will depend on building it as planned and on its operation under expert supervision until all the minor details are in perfect running order. This policy has been found to be good business by the East Jersey Water Co. and the Hackensack Water Co. and doubtless the Board of Public Service of Columbus will adopt the same plan. Its work to date has made the city the cynosure of municipal and sanitary engineers all over the world for it exhibits the best kind of engineering progress, that based on scientific research and embodied in well-designed structures.

Heavy Electric and Steam Traction.

At a meeting of the New York Railroad Club held last week the superintendent of motive power of the Baltmore & Ohio R. R. Mr. Muhlfeld, read a paper on the operation of the heavy electric and Mallet locomotives used by that road. His experience with these types convinces him that while some steam railroads present attractive opportunities for electrification, particularly in districts where current can be furnished at low cost, electricity cannot be expected to supersede steam until electric locomotives do better than they have. He considers that they may be justified in some instances because they will increase the capacity of the line, on account of their more rapid acceleration, but their initial cost and what he considers their extravagant power consumption debar them from all but a few classes of service, in his opinion. While there is of course no immediate prospect of trunk line operation by electricity except possibly on the New York, New Haven & Hartford R. R. between New York and New Haven, this is not due to any showing made by the Baltimore & Ohio electric locomotives. The figures of their operation given by Mr. Muhlfeld are a welcome addition to the general information on the subject, but they are not conclusive for the very good reason that they were obtained with special locomotives.

Inasmuch as these figures will doubtless be quoted considerably, owing to the high official position of Mr. Muhlfeld, it may be well to point out why their value is so limited in any general problem of heavy traction. The electric locomotives were built for the special purpose of hauling as heavy trains as can be coupled together without pulling out the drawbars, and their speed was intentionally made very low. The station furnishing them with power is not economical, as stations go to-day, and the system of power distribution is costly and wasteful of power. In spite of these defects, which do not exist in any electric system designed for standard railroad conditions to-day, the equipment is manifestly giving a good account of itself or it would be scrapped. This special type of locomotive, obsolete in its design except so far as it answers the unusual conditions existing in Baltimore, should not be compared with a Mallet compound steam locomotive working under conditions calculated to develop its highest efficiency. Such a comparison is about as valueless as one between a span of trotters and a pair of oxen; it affords no information of much account concerning the usefulness of either in their special services. Moreover the figures in both cases are the result of but the first year of operation, a fact that Vice-President Vaughn of the Canadian Pacific Ry. mentioned at the meeting as showing their inconclusive character. Mr. Gaines, mechanical engineer of the Philadelphia & Reading Ry., endorsed this opinion by asserting that his experience with such high pressure as is carried in the Mallet locomotive on the Baltimore & Ohio indicates that the boilers wear out more rapidly than usual, and whether such will be the case with this particular locomotive can only be determined by further experience.

At the present time nobody knows definitely just what electric locomotives will do, but inside of a year we shall have a great deal more information. We know, however, that the New York Central locomotives are a great improvement over those at Baltimore, not only in their weight per horse-power, a detail to which Mr. Muhlfeld attaches a higher importance than seems justifiable, but in many other respects. Their tests on the trial track near Schenectady have shown that they will accomplish all that was required of them and considerably more. Such locomotives, supplied with current from up-to-date power stations by means of an economical system of power distribution, will unquestionably furnish much better figures than those of the Baltimore locomotives. Moreover, the alternating current equipment of the New York, New Haven & Hartford R. R., still to be tested publicly, answers even more closely the requirements which Mr. Muhlfeld gives in his paper for satisfactory electric locomotives. Two of his requirements were particularly referred to by Mr. Scott at the meeting. One of these was economical operation at different speeds and loads, which is met by the use of a transformer tapped to give any desired number of speeds. The other requirement was the prevention of the independent revolution of wheels coupled in series, which happens when the first motor in series takes more than its share of power, causing its pair of wheels to slip. With alternating current operation the motors can always be connected in parallel thereby giving a condition in which each pair of wheels is held separately.

Even accepting Mr. Muhlfeld's figures as correct for the general case of heavy traction, they seem to miss the pith of the whole matter. It is mainly a question of volume of traffic. All that is necessary to convince an engineer of this fact is to consider the relatively small power stations needed by the New York Central road to handle its enormous traffic in the Electrical Zone about New York with the great power plants required by the street, elevated and subway railways in that city. The amount of power required on a steam road is not very great even with heavy traffic, and it is for this reason that the generation of electricity and its distribution for long distances offers little attraction to railway managers at present. It is too expensive. Where trains run with sufficient frequency or there is a long, heavy grade, electricity will find an early application. This will not be because the locomotive happens to be more or less economical than a steam locomotive, but because the whole electric equipment of stations, line and locomotives enables the railway to do something that it cannot do with steam locomotives.

The Character of Correspondence School Teaching.

There is a tendency in some quarters to ridicule the character of the instruction in correspondence courses, and to confuse the work of the good schools with the pretensions of the bad ones. Courses in singing and nursing given by mail are naturally open to criticism, but much of the work done by the well-established schools is in some respects of high character. This can be seen from even a hasty examination of the text-books used for instruction. Several of the books issued anonymously by one of the schools were prepared by men of the highest professional standing. They have been modified from time to time by the staff of instructors so as to answer the requirements of the students, as indicated by their questions, and are now being revised by other specialists in order that they may be brought strictly up to date. Another school has recently published a number of books to which the authors' names are attached. For example, the book on railroad engineering is by Prof. Walter Loring Webb, that on water supply by Prof. Frederick E. Turneaure and that on masonry by Mr. Austin T. Byrne. They are very good; not so elaborate as some of the treatises on these subjects, but accurate and covering all the essential elements of their respective subjects. Anybody who really masters one of them can solve the ordinary questions concerning its subject. A good many engineers would find them instructive as well as interesting reading. In short, the text-book feature of the best of these schools cannot be adversely criticized.

The serious problem of correspondence instruction does not lie in this line but in the revision of answer papers. In studying a subject in this manner all the incentive that comes from the rivalry of the classroom and the inspiration of a good teacher is lost. It is pretty hard for even the most conscientious and capable instructor to transmit much enthusiasm in care of a two-cent stamp. Correcting examination papers is generally considered the greatest drudgery that falls to the teacher, and correspondence instruction is done only by the medium of such papers. It is accordingly the hardest kind of teaching on the instructors, if well done. Teaching does not consist of mere correction of errors in recitations but in helping pupils over hard places and in inspiring them with real interest in their subjects. It is in this respect that the correspondence schools are necessarily weak. An observation of the returned papers sent by severals pupils in such schools shows that the marking is much like that of a civil service examination and the pupils do not receive as much help as they need. Very likely this is because the number of papers to be gone through in a day by an instructor is too great for him to put much time on any one, or possibly he lacks the inclination to do more than indicate mistakes and briefly outline the correct answer. Some of the drawing sheets returned to the pupils were criticized very poorly, attention being paid to trivial details of finish while defects in the real work were not explained as pointedly as they should be. As a whole, the criticisms were apparently conscientious and correct, but absolutely colorless. They might have been made by a rubber stamp so far as indicating to the pupils that the instructors took any interest in their work.

These statements are not made in any spirit of fault-finding with the schools. They are private enterprises which must be run with a due regard to expenses. They have no endowments, no alumni funds, no donations from Mr. Rockefeller to help them over hard places. They are doing good work. The statements made above are intended solely as an answer to a good many inquiries concerning the character of correspondence school instruction. It is a good return for the money paid for it. It is based on good text-books and a good system of correcting answer papers. On the other hand, the degree of success which may be expected to result from taking a course in any subject will depend mainly on the person taking it. There is apparently a tendency to take courses too far advanced. Some correspondence school pupils have been observed struggling with engineering subjects when they should be grounding themselves in mathematics. They were apparently too ambitious to get on and accordingly had to flounder through the deep places. One or two of them had begun to lose interest and would evidently soon drop out on that account. Some complained that they could not afford time for the work, much as they liked it. The net result of the observations was that anybody who had the preparation, inclination and determination to take a course felt paid for doing so.

THE WATER FILTERING AND SOFTENING WORKS AT COLUMBUS, OHIO.

The plant now under construction at Columbus, Ohio, for filtering and softening the public water supply of that city contains several interesting features which are steps in advance for works of improved water supplies. It has a nominal daily capacity of 30,000,000 gal. and is thus by far the largest of any water softening plant in the world. Like many softening plants for railroad and industrial establishments (see Handy's paper, Trans. Am. Soc. C. E., Vol. 54, Part A, p. 1), it will eliminate or largely reduce the sulphate hardness (incrustants or permanent hardness) as well as the carbonate or temporary hardness. In this regard it differs from the municipal water softening plants at Winnipeg, Man., (Engineering Record, June 14, 1902), and Oberlin, Ohio, (Eng. Rec., Oct. 7, 1905), and so far as known from the plants abroad, of which the one at Southampton, Eng., (Eng. Rec. Feb. 4, 1899), is fairly typical. The Columbus plant is also unique in that mechanical filters will be used for the final removal of the precipitates resulting from the softening treatment and in that systematic use will be made of the relatively large amount of the gelatinous hydrate of magnesia to coagulate the Scioto River water, which at times is very turbid. Another feature of interest and importance is the simple way in which a small portion of the raw water will be by-passed to the settling basin to eliminate remaining traces of caustic alkalinity (lime water) which at some plants have given more or less trouble through the formation of a fine hard precipitate of calcium carbonate in pumps, pipes and faucets.

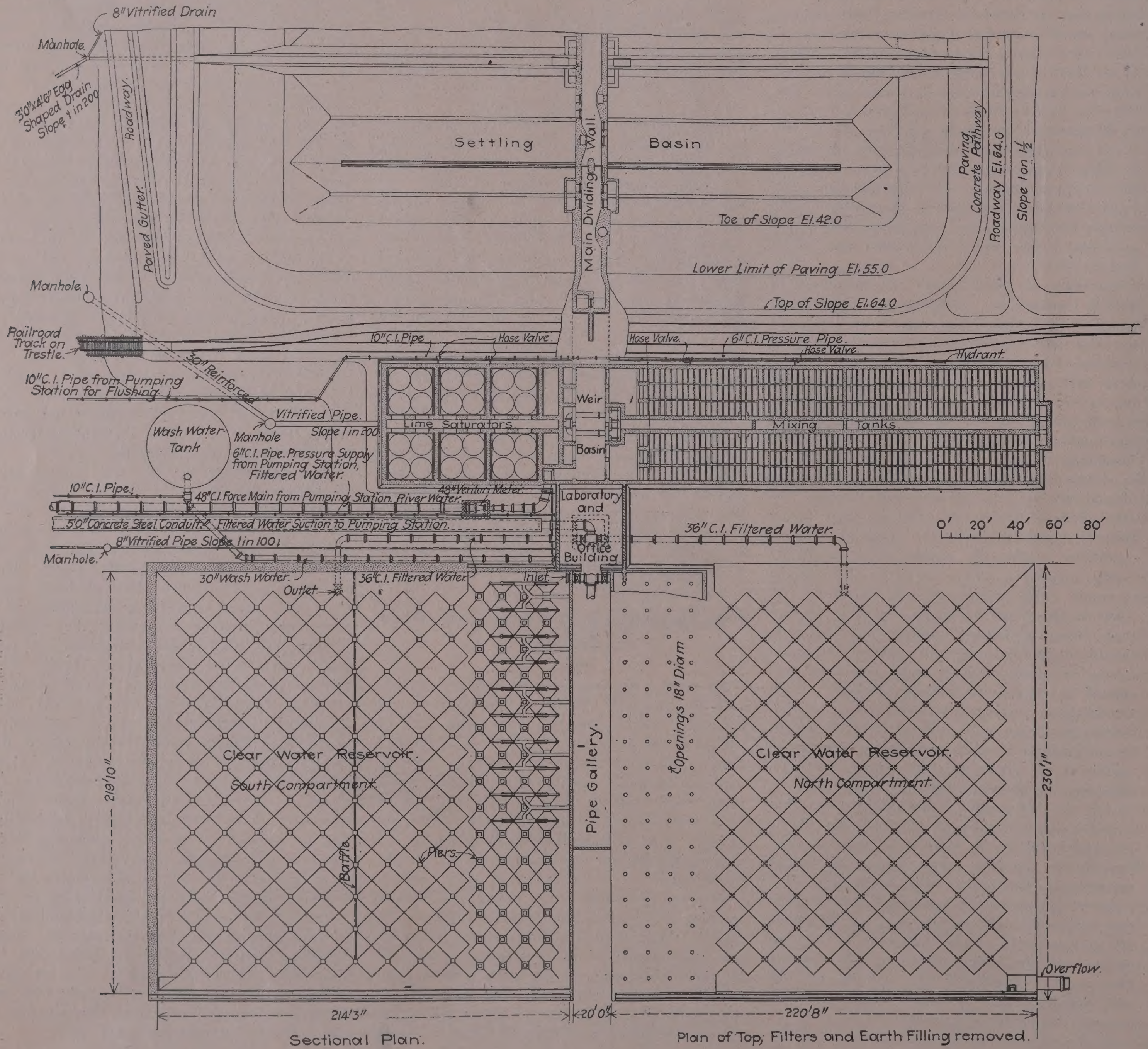
To understand the main features of the Columbus plant it is necessary to describe first the six principal steps prior to filtration, which are as follows:

First.—The raw river water is first treated with a saturated solution of lime water to combine with all or nearly all of the free and half-bound carbonic acid and with the magnesia. This reduces the carbonate hardness and, when the reduction is completed, causes the lime to appear as a fine and more or less granular precipitate (carbonate) while the magnesia separates out as a gelatinous precipitate, which is a hydrate.

Second.—The above reaction takes place very slowly when the water is at rest, especially at winter temperatures. To complete the reaction promptly it is necessary to stir the water for an hour or so or to give it a similar treatment. This is done by passing the water for about an hour through highly baffled mixing tanks in which it can be kept at a velocity of about 0.3 to 0.5 ft. per second, as found desirable. In this way a large share of the resulting precipitates are held in suspension and the double purpose is accomplished of completing the softening reactions and of using the precipitates for coagulating the turbid water.

Third.—Some 10 or 15 minutes after the river water and lime water enter these lime-mixing tanks, a solution of soda ash is applied to reduce the sulphate hardness. This causes the lime to be converted into a normal carbonate, which, under the existing conditions, is nearly insoluble. This reaction is also a slow one and is facilitated by the stirring which the water receives in the mixing tanks in the presence of the resulting precipitates.

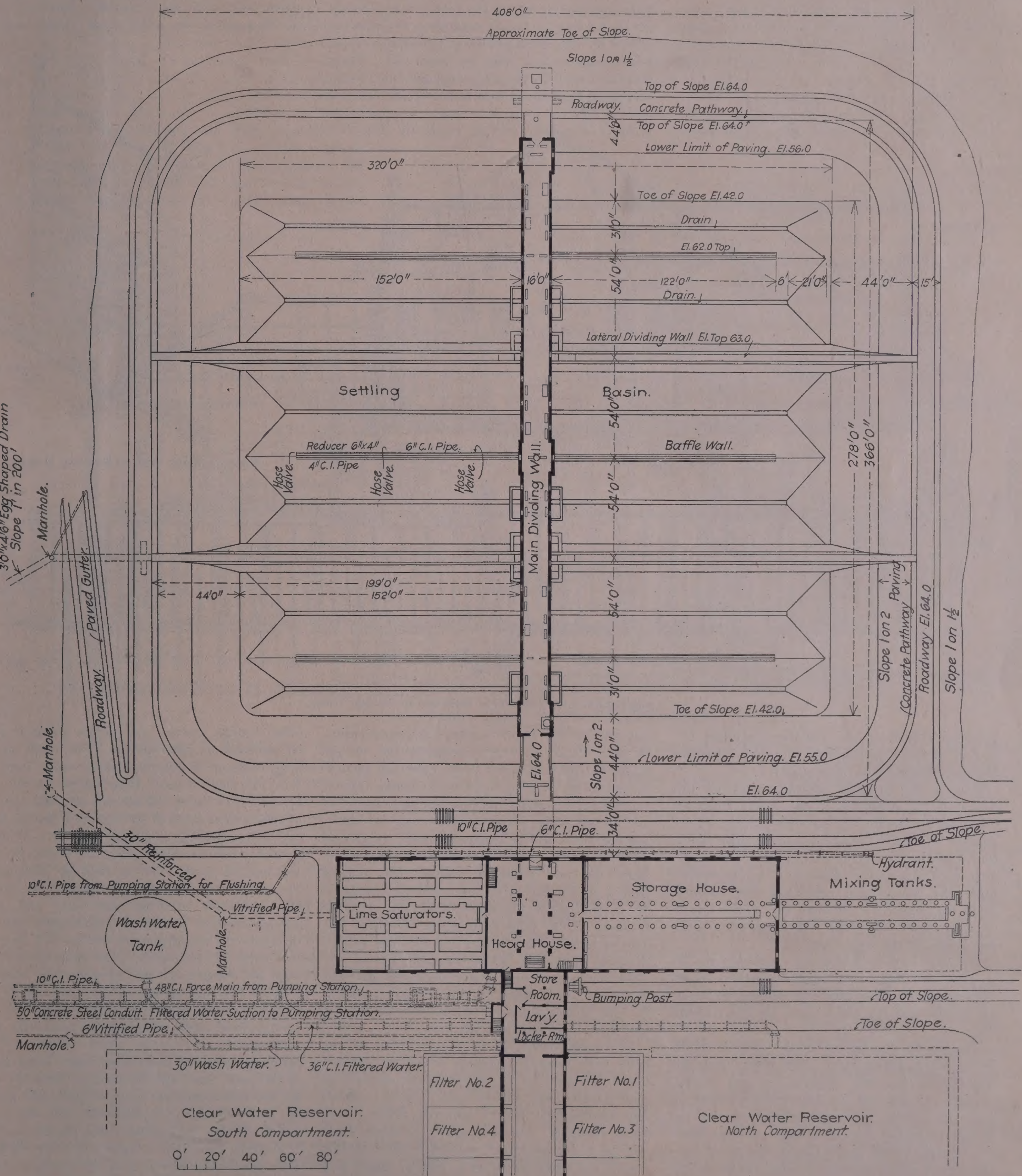
Fourth.—After the water has passed through



GENERAL PLAN OF CLEAR WATER RESERVOIR AND ADJACENT STRUCTURES the mixing tanks it is led to the settling basins holding about 12 hours' flow at full capacity of the plant. The basins are designed with several compartments to be used in series or in parallel as found most effective in practice under varying conditions. It is intended to remove the water from these basins and apply it to the filters as soon as the softening reactions are sufficiently completed and before the magnesia precipitate is entirely deposited. By this procedure it is expected that very little coagulant will be required, probably none at all for months at a time. This use of magnesium hydrate as a coagulant is quite distinctly different from the lime treatment of the Ohio River water in 1899 at Cincinnati, where the magnesia contents are too low to be of practical value. On the lower Mississippi and elsewhere this process has apparently a field of usefulness.

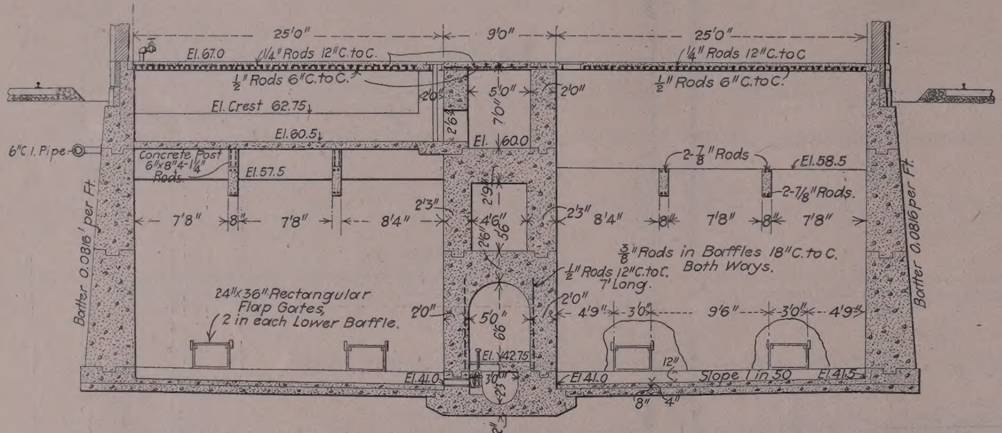
Fifth.—When required solutions of sulphate of iron or of sulphate of alumina may be added to the partially settled water to complete the coagulation of the water when unusually turbid.

Sixth.—When it is desired to remove the water from the settling basin and filter it before the softening reactions are entirely completed the last traces of caustic alkalinity (lime water) may be removed by mixing with the settled water a small percentage of raw river water and allowing the mixture to remain a few hours in the basins before filtration. This, of course, increases slightly the hardness of the filtered and softened water.

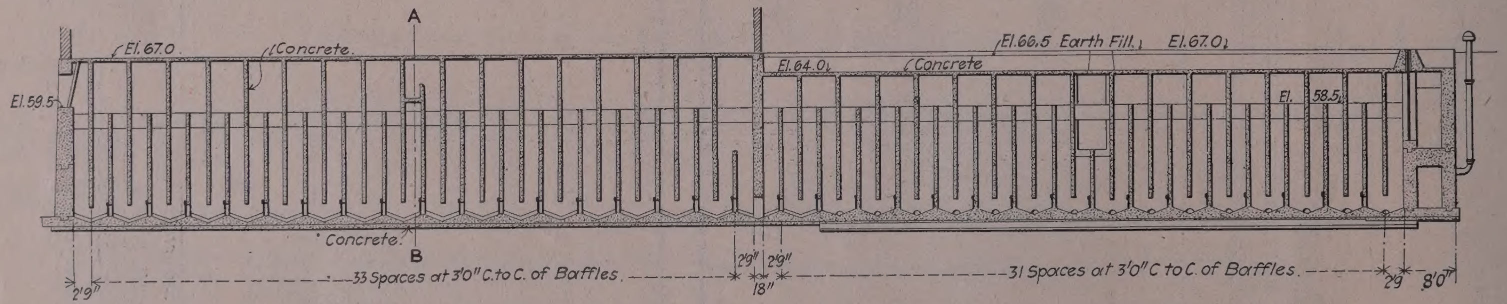


GENERAL PLAN OF SETTLING BASIN AND ADJACENT STRUCTURES

While some features of this project have not been developed experimentally with the thoroughness characteristic of the investigations upon sand filtration at Lawrence or upon mechanical filtration at Louisville, yet the fundamental principles and the more essential details have been very carefully studied. Fortunately the Sewage Testing Station at Columbus was in operation while this plant was being designed. Under the direction of Messrs. Geo. W. Fuller and John H. Gregory many features of significance in industrial softening plants were investigated under Columbus conditions at the testing station under the supervision of Mr. Johnson, the engineer in charge, who made a special report upon the subject. The chemistry of the process in its local application was developed with especial thoroughness by the chemist of the station, Mr. A. E. Kimberly, who read a paper at the Havana meeting of the American Public Health Association in January, 1905, upon some of the purely technical aspects of the problem, including improved methods of analysis (Journal Infectious Diseases, Supplement, May, 1905).



Section A-B.



Longitudinal and Transverse Sections of Mixing Tanks.

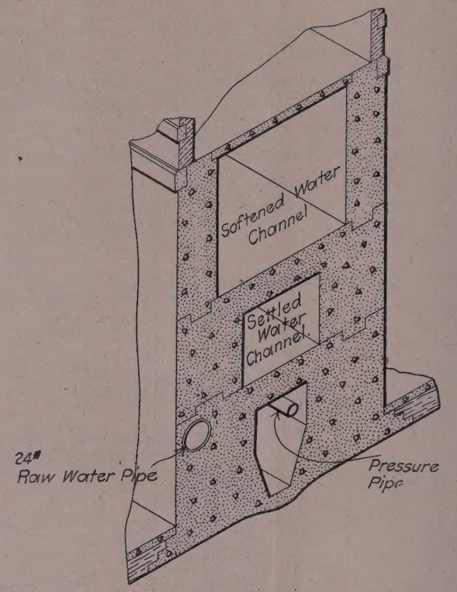
One of the principal characteristics of this design is the flexibility of the works from the operating standpoint. It was the purpose of the engineers to build the works so that their operation would be as simple, effective and economical as it is possible now to make it. This necessarily made the construction somewhat more complicated and expensive, although this special aspect of the construction does not represent a large percentage of the total cost.

The works are located about 1 mile beyond the western city limits and near the Scioto River. They are about 1 mile above the West Side pumping station and 4½ miles below the new storage dam.

The general arrangement of the works is shown in the accompanying plans. The river water, impounded by the dam described in this journal on Sept. 9, 1905, will be delivered eventually by a gravity conduit to the purification works, but at first the water will be allowed to flow down the natural channel of the river to the new pumping station adjoining these works, whence it will be delivered by centrifugal pumps through a 48-in. force main to the purification and softening works. The new pumping station soon to be constructed will contain at first two 25,000,000-gal. triple-expansion vertical pumps, to deliver the purified water to the city mains.

The force main discharges the raw water through a Venturi meter into the middle of the headhouse, where its distribution is controlled by various weirs, enabling the treatment of the raw water to be varied as changes in its character may make necessary. At one side of the headhouse is the saturator house containing six lime saturators, and at the other is the storage house, for lime, soda and coagulant, covering one end of the two mixing tanks or basins, their other end being covered with an earth fill. These three houses, with the laboratory and office rooms projecting from the central part or headhouse, are treated architecturally as a single structure, and separate the open settling reservoirs from the ten covered filters and covered clear-water basins. A spur track is brought alongside the storage house to enable supplies to be delivered readily. A special 10-in. pipe from the pumping station furnishes river water for flushing the saturators and mixing tanks, while purified water for washing the filters will be delivered from a reinforced concrete water tower, to which it will be pumped from the new pumping station. The settling basins, in six baffled compartments, are 408x366 ft. on the top of the inside slope and about 20 ft. deep. Their capacity is about 15,000,000 gal. The two clear water basins and the pipe gallery dividing them are about 220x461 ft. In the clear water reservoirs about 10,000,000 gal. can be stored. The main building is about 240x62 ft. The mixing tanks are 67x209 ft. by 20 ft. deep and hold about 1,000,000 gal.

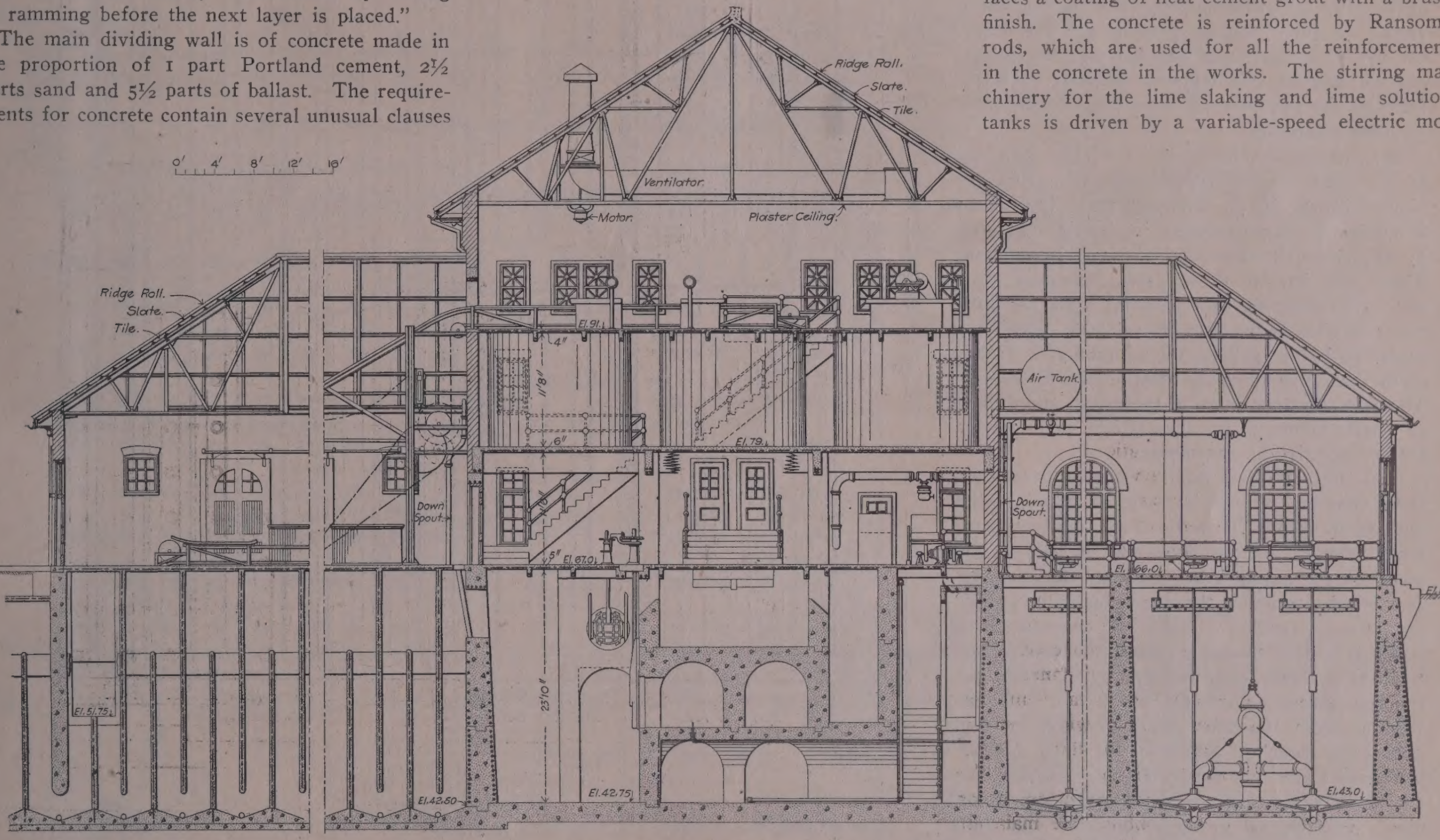
The embankments of the settling basin will be built with material obtained from the excavation. This material must be free from stones over 3 in. in size, and will be spread in 6-in. layers and consolidated with a grooved roller or by hand ramming. On the inner 1:2 slope there will be a dry pavement running down from the top of the embankment to a vertical depth of 9 ft.; this consists of limestone blocks resting on a broken stone or gravel backing. The slopes and the bottom of the basin will be lined with a puddled mixture of one part of plastic clay and two parts of sandy gravel. On the slope below the paving and on the bottom the puddle will be covered with a 6-in. layer of concrete. The puddle will be mixed by machine and then placed in layers 4 to 6 in. thick, which will be consolidated while drying out by a grooved roller. The general requirements for the puddle were unusually complete and read as follows:



Dividing Main Wall of Settling Basin.

"The puddle shall consist of a mixture of stiff plastic clay and sandy gravel. The clay shall be of good quality, free from loam, mica or other foreign matter, and before using it shall be approved by the engineer. The sandy gravel shall consist of approximately equal parts of sand, varying in sizes from coarse to fine and of such size that it will all pass through a screen having a clear mesh of ¼ in., and of gravel varying in size from ¼ to 1 in. in diameter. If sandy gravel is found in the excavation, it may be used for making puddle, but it shall be screened to the proper size and shall be washed to remove the admixture of loam, dirt, clay and other foreign matter. In general the puddle shall be mixed in the proportions of one part of clay and two parts of sandy gravel, but these proportions may be changed at any time by the engineer whenever in his opinion it may be necessary in order to secure water-tight work. The clay and sandy gravel shall be mixed by machinery in a screw-paddle continuous mixer or pug-mill or by other approved machinery, water being added at the same time, and the mixing continued until all the clay lumps are softened and well broken up and thoroughly incorporated with the sandy gravel. While the puddle is in a plastic condition it shall be placed in a layer 4 or 6 in. thick, or such other thickness as may be directed, over a large surface and left to partially dry out. During the process of drying-out the puddle shall be thoroughly rolled with a grooved roller weighing at least 1,000 lb. per lineal foot and at least 3 ft. long, or wherever in the opinion of the engineer it is impracticable to use a roller, the puddle shall be thoroughly rammed until all shrinkage cracks are closed, and the entire mass has become thoroughly consolidated and made water-tight. The exact time required for the process of partially drying-out cannot be determined in advance, but shall continue until the puddle has a hard impervious surface. The puddle shall be sprinkled with a fine spray of water during the process of rolling or ramming, or any time when so directed. After the first layer has been placed, an additional layer or layers shall be placed until the required thickness is obtained. Each layer shall be allowed to dry out and become thoroughly consolidated by rolling or ramming before the next layer is placed."

The main dividing wall is of concrete made in the proportion of 1 part Portland cement, 2½ parts sand and 5½ parts of ballast. The requirements for concrete contain several unusual clauses which will be mentioned in detail later. The accompanying cross-section of this wall shows the arrangement of the softened water channel at the top, the settled water channel in the middle and the drainage channel at the bottom, with the 24-in. vitrified raw-water pipe embedded in the masonry. The lateral dividing walls or baffles of the settling basin are made of 1:3:7 concrete and floors of 1:2½:5½ concrete.



Section through Storage, Head and Saturator Houses.

In the softened water channel are four coagulant discharge grids controlled by gate valves with stems rising into the elongated gate house surmounting the main dividing wall, and connected by a 3-in. lead-lined pipe with the funnels of the chemical feed regulators in the headhouse. Running lengthwise of this dividing wall is a 24-in. pipe conveying raw river water from the headhouse.

In the accompanying cross-section through the headhouse, supplementing the general plan of the layout, the reader is assumed to be looking toward the filters and clear-water basins. In order to trace each detail of the passage of the water through this headhouse many more illustrations would be needed than the condition of the work at the present time warrants, as the purpose of this article is merely to give a general idea of the purposes of the plant and the character of construction adopted in its several parts.

The raw river water, after passing through the Venturi meter, enters the middle of the headhouse where is located a weir basin about 15x59 ft. by 5½ ft. deep. Here are a series of set and adjustable weirs which allow three special adjustments of the flow to be made in addition to delivering the main body of water to the mixing tanks and to providing an overflow for conveying to the settling basin any surplus water which accidentally for short periods may be delivered to the headhouse by the centrifugal pumps. The special purposes for which known but varying quantities of river water are removed from the weir basin are, first, to provide a saturated solution of the applied lime; second, to mix with the soda solution and facilitate the speed of reaction of the soda which enters the mixing tanks a short distance from the inlet; and third, to provide water through the 24-in. pipe extending along the dividing wall of the settling basins for use in eliminating caustic alkalinity when necessary.

Lime will be applied as a substantially clear and saturated solution having an approximately uniform strength of about 65 grains per gallon. A portion of the raw river water will be diverted from the weir basin. Milk of lime will then be added to it, and it will afterwards enter a closed channel in the longitudinal party wall between the saturators, which are six in number, each being 25x25 ft. and 20 ft. deep. The treated water is conveyed to the bottom of each saturator through branch pipes where it is stirred mechanically. These saturators are operated on the continuous upward displacement plan, the clear lime water being weired from the top into an open channel at the top of the longitudinal concrete party wall. Thence the lime water is conveyed by a cast iron pipe through the weir basin to the inlet of the mixing tanks where it meets the main body of river water.

Ten per cent. suspension of milk of lime will be used. No unusual features are used in preparing the solution of soda or coagulant (sulphate of iron or alumina). For each chemical an automatic regulator is provided to make the flow proportional to the quantity of river water pumped to the works.

The suspension of milk of lime and solutions of soda and coagulant are made up on the third floor of the headhouse, in a room fitted with an overhead duct and an electrically driven fan to ensure thorough ventilation and reasonable freedom from dust. The materials are delivered in bags to this room from the store house over the mixing tanks by an electrically driven apron conveyor. The milk of lime and the solutions flow by gravity through the storage tanks and then through the regulators to the water to be treated.

All tanks for preparing and storing the solution are made of 1:2:4 concrete having on all faces a coating of neat cement grout with a brush finish. The concrete is reinforced by Ransome rods, which are used for all the reinforcement in the concrete in the works. The stirring machinery for the lime slaking and lime solution tanks is driven by a variable-speed electric motor by noiseless chains. The stirring machinery for the lime saturators is driven by two variable-speed electric motors connected with the jack shaft by silent running high-speed chains. The jack shaft is belted to the line shaft, which in turn is belted to counter-shafts geared to the stirrer heads. The slaking and dissolving tanks have steam heating connections. The solutions are kept in reinforced concrete tanks on the second floor fitted with compressed air pipes for keeping their contents stirred, and are fed through two sets of regulators on the first floor. The lime and soda solutions are supplied through wrought-iron pipes, and the coagulant through lead-lined pipes. The balanced inlet valves in the tanks of the coagulant regulator are of a special composition, and the copper floats in these tanks are given two coats of rubber solution. All iron surfaces which would come in contact with the coagulant are covered with lead.

The air compressor used in stirring the solutions of soda and coagulant and for supplying air to the filters during washing is an electrically driven machine with a capacity of 100 cu. ft. of free air to a pressure of 60 lb. per square inch.

The air will be delivered to tanks carried by the roof trusses of the saturator house, and the motors have a self-starting device so that the pressure will be maintained constantly in the tanks.

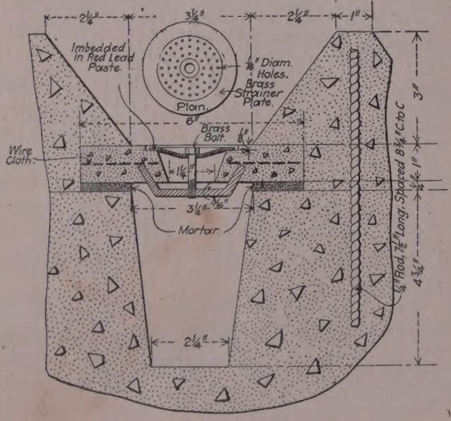
The large baffled mixing tanks for mixing the lime water with the main body of river water are one of the most novel and interesting portions of the entire works. As already stated and as will be observed from the illustrations, river water and saturated lime water enter at the inlet adjoining the weir basin. A small portion of the river water containing the soda solution will be applied a short time after the main body of the river water and the lime water have entered the tank. The mixed water may be taken off at the end of the tanks or before the end is reached. The baffles are only three feet apart on centers, and those that rise from the floor are fitted with gates opening both ways. The bottoms of the tanks have drainage channels running transversely to quick opening gates in the dry chamber under the dividing wall, so that the sludge can be flushed out without difficulty. Similar facilities are provided for removing sludge from the lime saturators.

The filters are substantially the same as those of the plant of the Hackensack Water Co. at New Milford, N. J., although there have been a number of improvements in details suggested by experience in the construction of that plant. There are ten of these units, arranged symmetrically about the pipe gallery. They are built over a portion of the clear water basins, which are separated by the gallery, the groined roof arches of the basins carrying the floor of the filter beds. The general construction of the pillars and roof is so clearly shown in the illustrations as to render further description unnecessary.

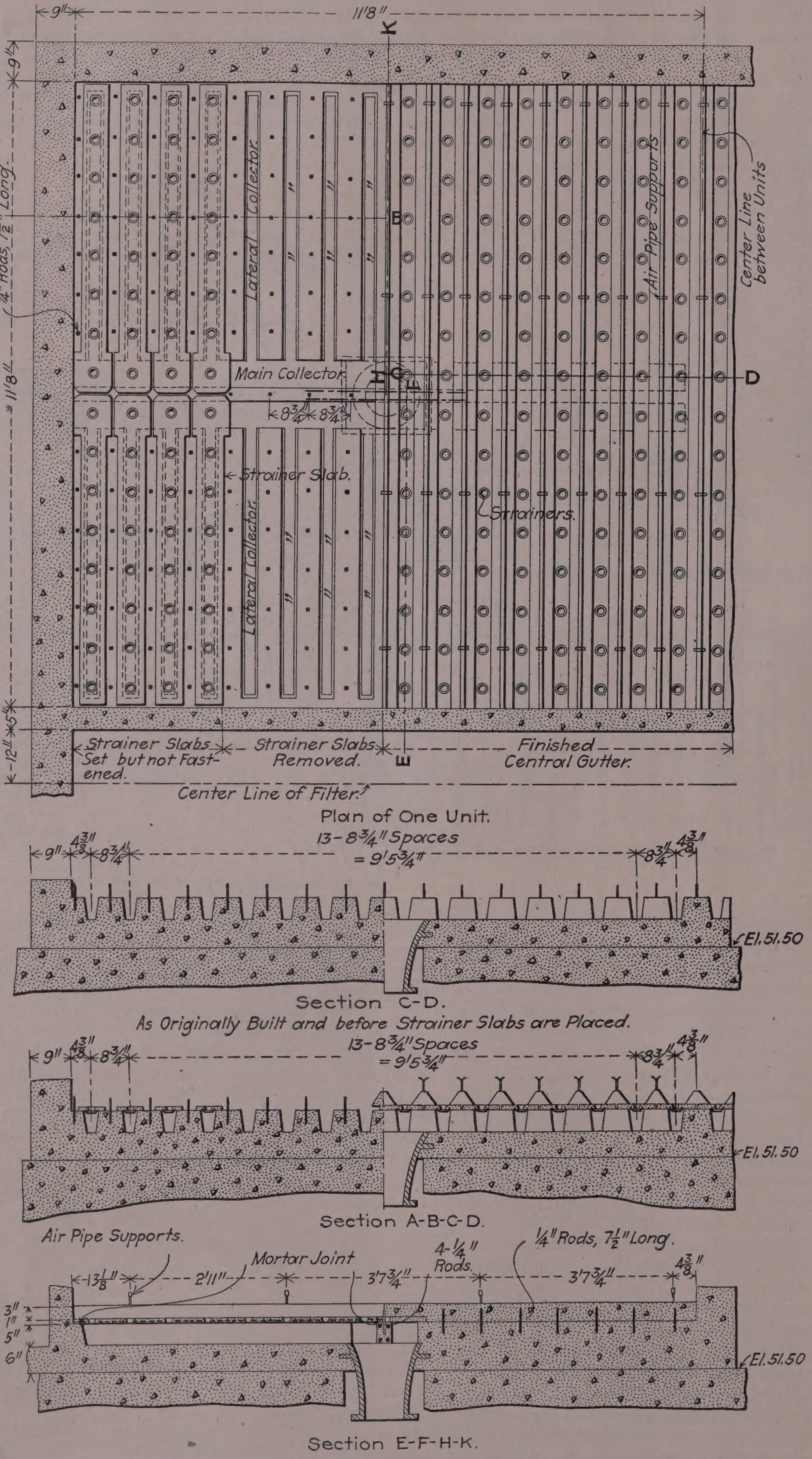
Each filter tank is built as a reinforced concrete monolith 46 ft. 8 in. long, 26 ft. 2 in. wide and 9½ ft. deep. The walls of the adjacent tanks are in contact, and the floors rest directly on the roofs of the basins below. Except for the few feet which lie under the operating gallery, they are covered with a reinforced concrete roof, which is built at the same time as the tank. Each tank is divided longitudinally by a reinforced concrete gutter or trough 24 in. wide and extending from the filter floor to about 1 foot above the sand. It serves as an inlet for the unfiltered water, but particularly as an outlet for the wash water, and also contains the main air pipe. This central gutter divides the tank into two independent sand beds and its walls carry four pairs of concrete columns which support the roof girders.

From each side of the central gutter run six lateral concrete gutters which serve as weirs for the removal of dirty wash water. Their sides are at a height of about a foot above the sand, and, for about 3 ft. from the central gutter, rise somewhat above the top edge of the latter, in order that a portion of the dirty water may be weired directly into the central gutter, which is connected with the drain.

The strainer and piping systems at the bottom of each filter are arranged in eight subdivisions, each of which has a separate outlet. The lateral waterways are channels formed in the concrete bottom of the tank, each 5 in. deep and 2¼ in. wide on the bottom. They serve for the collection and removal of filtered water and for the distribution of the water for washing. Over them are placed the strainer slabs containing the strainers themselves, which are brass plates containing 1/16-in. holes. The concrete waterways of the strainer system are spaced on 8¾ in. centers and the perforated brass plates over the same waterway on 8¾ in. centers. The strainer slabs are bedded in mortar and are made independently of the rest of the filter masonry. The laterals discharge into eight main collectors formed in the concrete bottom of the tank. Each main collector through a casting in the filter floor connects with the piping below the floor. This



DETAILS OF STRAINER

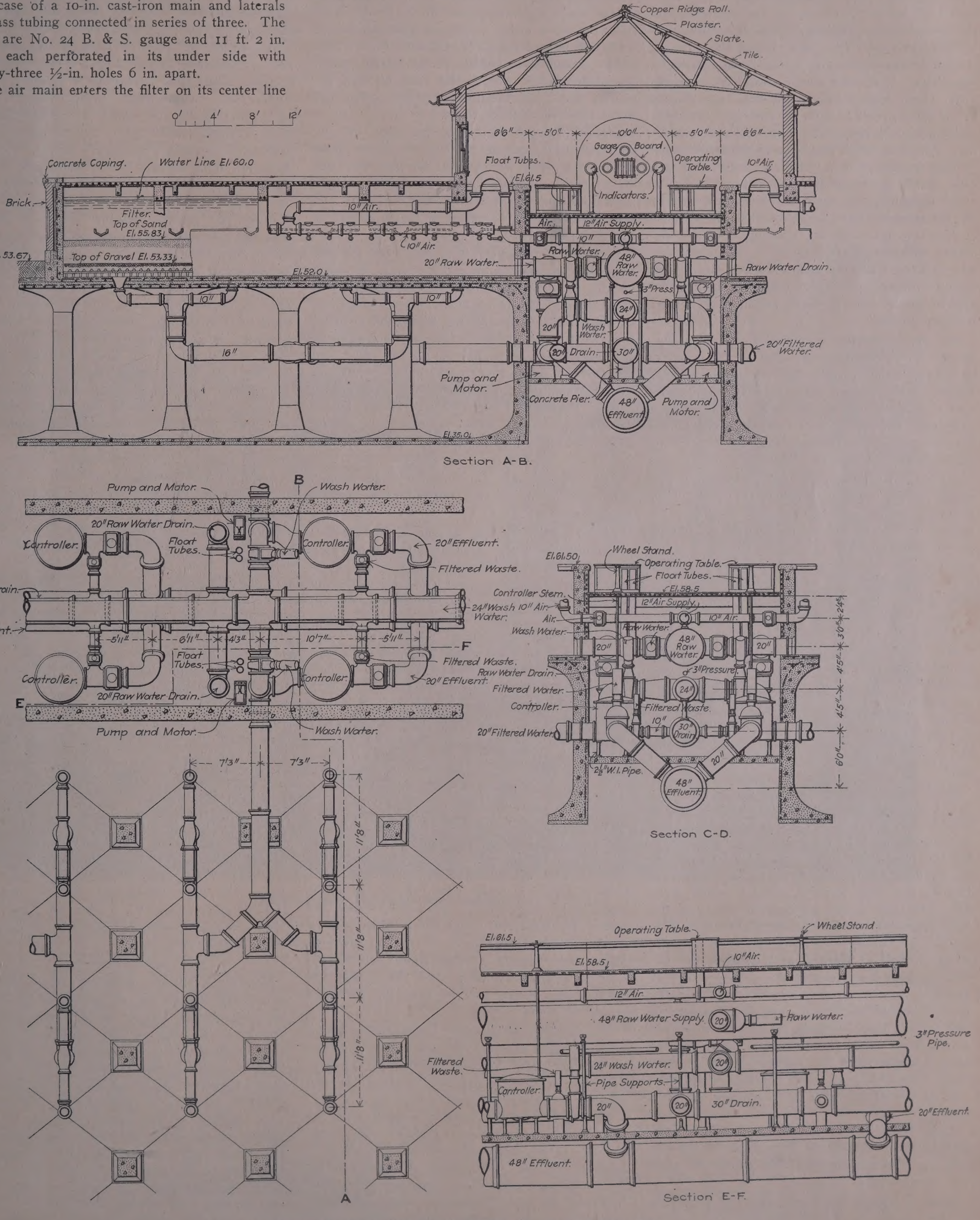


DETAILS OF STRAINER SYSTEM OF FILTER UNIT piping in turn unites to form the main effluent pipe through which filtered water also enters the filter during washing. The strainer slabs are held in place by concrete ridges, which are provided with short vertical supports for the pipes which supply air for agitating the sand bed during washing.

The air pipe system for supplying compressed air for stirring the sand in a filter consists in each case of a 10-in. cast-iron main and laterals of brass tubing connected in series of three. The tubes are No. 24 B. & S. gauge and 11 ft. 2 in. long, each perforated in its under side with twenty-three ½-in. holes 6 in. apart.

The air main enters the filter on its center line at the level of the top of the central gutter, but immediately inside the wall rises vertically to a U-bend, the top of which is about 3 ft. above the water level on the filter. From the U-bend it drops to a level about 1 ft. below the surface and runs horizontally to a point over the middle of the gutter, where it again drops and then extends longitudinally in the gutter in both directions. The U-bend acts as a trap to prevent water entering the air pipe and causing trouble. The connections for the laterals are made in the bottom of the lowest run and are spaced about 2 ft. 2 in. apart.

Over the strainers and the air pipes there are graded gravel and filter sand. The tops of the strainers are 6 in. above the filter floor surface;



DETAILS OF PIPING OF FILTERS AND IN PIPE GALLERY the top of the gravel is 10 in. above the strainers; the sand is 2½ ft. deep, and the usual depth of water will be 4 ft. 2 in. above the sand, or 8 ft. above the filter floor.

The gravel will be graded from 1/16 to 1 in. in size. The filter sand is required to have a uniformity coefficient of 1.5 and an effective size between 0.36 and 0.44 millimeter; not more than 1 per cent. of it may be smaller than 0.25 millimeter. A special clause in the requirements for the sand reads as follows: "Especial care shall be taken in transporting and placing the sand to prevent contamination and to keep it from becoming dirty. Any sand which may have become dirty, either before or after it has been placed in the filters, shall be either washed, or removed and replaced by clean sand in a satisfactory manner. All sand which has been contaminated other than by dirt will be rejected. In placing the sand in the filters great care shall be taken to avoid disturbing the upper layer of gravel. After the sand has been placed it shall be washed at least ten times by the washing devices connected with the filters. Each of these separate and distinct washings shall be of at least five minutes' duration, and the wash water shall be applied at the rate of eight gallons per square foot per minute."

All the connections described are properly valved for controlling the flow of the water according to the operation being performed. The design of the effluent pipes is intended to furnish a channel of equal resistance for the water from each portion of the filter to the controller, thus promoting the uniformity of the movement of the water through the filter.

All the valves necessary for the operation of the filters located in the pipe gallery, are fitted with hydraulic lifting cylinders, so that they may be opened or closed from the operating gallery, which is directly over the pipe gallery. A 3-in. wrought-iron pipe from a 6-in. pressure main from the pumping station is carried through the pipe gallery and supplies filtered water under pressure for the hydraulic cylinders, and for the miscellaneous uses in the building. The various devices for controlling each filter are mounted on an operating table, and the eight tables are placed symmetrically along the two sides of the operating gallery. The floor of this gallery is 3 ft. below the tops of the filter walls and 1½ ft. below the water level, in the filters, so that when standing on this floor a person can easily look into the filters.

Special interest attaches to this plant because it is a most conclusive demonstration of the important part that concrete has attained in American engineering. In the general use of concrete for the filters, for the elevated tank containing the wash water and other details of this nature, it follows the same general designs which were first elaborated in the purification works of the East Jersey Water Co. and the Hackensack Water Co., but, owing to the arrangements for softening as well as filtering at Columbus, the extent to which concrete is employed is considerably greater. Special attention has been paid in the preparation of the plans and specifications to call for all those methods of manipulation and arrangement which previous experience on the same kind of work has shown to be desirable. Nine classes of concrete are required, as follows:

Class A, mixed 1:2:4 and used for the filter tanks.

Class B, mixed 1:2:4 and used for the solution tanks on the second floor of the headhouse and for the wash water tank, except its piers and foundations.

Class C, mixed 1:2:4 and used for the floors of the headhouse, the preparation room, offices and laboratory, the store room, lavatory, locker room and filter gallery, the machinery and upper floor of the main dividing wall of the lime saturators and gate house; the stairways in the superstructure and substructure of the main buildings, the outside steps and the roof of the mixing tanks in the storage house

Class D, mixed 1:2½:5½, used in the piers in the first story of the headhouse, the piers and vaulting of the clear water reservoir, the piers of the wash water tank, and those in the store room, lavatory, locker room and basement below.

Class E, mixed 1:2½:5½, and used for the roof of the mixing tank outside of the storage room, the baffles in the clear water reservoir and the mixing tanks, and the filtered water conduit and drain from the settling basin.

Class F, mixed 1:2½:5½, and used for the deflectors in the settling basin at the outlets from the main dividing wall, for the floors of the clear water basin, settling basin, pipe gallery, lime saturators, mixing tanks, substructure of the headhouse and the basement at the west end of the pipe gallery.

Class G, mixed 1:2½:5½, and used for the main dividing wall of the settling basin, the walls of the clear water reservoir, the interior and main walls of the lime saturators, the outside and dividing walls of the mixing tanks, the walls of the substructure of the headhouse, the walls of the substructure of the laboratory and office, and the culverts under the railway embankment and at the overflows of the clear water reservoir.

Class H, mixed 1:3:7, and used for the lateral dividing walls and baffle walls of the settling basin and the foundations of the wash-water tank.

Class I, mixed 1:2:4 and used for water tables, belt courses, window sills, lintels and the coping on filters.

It will be noticed that several of these classes are nominally of the same proportions, but as a matter of fact they differ materially for other reasons, which will be evident from the following notes concerning the materials used for the concrete and their manipulation. The sand must be well graded from fine to coarse particles and screened to reject all grains larger than ¼ in., as well as to reduce the amount of very fine material to 3 per cent. or less. The ballast may be either broken stone or gravel, screened into three sizes; No. 1, ¼ to ¾ in.; No. 2, ¾ to 1½ in.; No. 3, 1½ to 3 in. The use of these three grades is explained in the specifications as follows: "The ballast in each class of concrete shall consist of one or a mixture of two or three grades of the ballast specified. The relative amounts of the grades of ballast in each class of concrete cannot be determined exactly in advance, but in general it may be stated that No. 1 ballast will be used in concrete which is to be deposited in places where the No. 2 ballast would be too large to give satisfactory work; that a mixture of the No. 1 and No. 2 ballast will be used in concrete which is to be deposited in places where the No. 3 ballast would be too large to give satisfactory work, and that a mixture of all three grades will be used for all other places."

It is intended to use very wet mixtures except at such places as dryer mixtures seem desirable to the engineer. Machine mixing is required. The concrete is to be deposited continuously and joggled or lightly rammed.

Classes G and H concrete contain stone as large as can be conveniently handled. The upper surfaces of all floors and roofs made of Class C concrete will be a stiff mortar of equal parts of Portland cement and sharp screenings of crushed limestone or other approved stone, not larger than ⅜ in. This material must be put on before the concrete has taken its initial set and must be screeded, floated and troweled to a smooth, even surface, after which it will be sprinkled with a dryer consisting of one part of sand and two parts of Portland cement, with enough blue-black to give the required shade to the surface. This dryer is sprinkled dry over the surface and then floated and troweled, and this process is repeated three times.

As a rule, the forms on exposed surfaces of concrete must be removed before the concrete has hardened and its surface rubbed with mortar composed of one part of Portland cement and two parts of sand, applied with a burlap swab and brushed down with a plasterer's brush; or the surface may be finished by being rubbed with a stiff wire brush, after which a thin coating of neat Portland cement grout will be applied and brushed down with a plasterer's brush. All surfaces not built against forms, which are not to have the granolithic finish already described, will be screeded and troweled to a smooth surface. The concrete for the vaulting will be so placed that the sections over each pier included between the center lines of the adjacent arches will be monoliths. Each filter tank will be a monolith. Special care will be taken with Class I concrete and its exposed surfaces will be colored to a depth of 1 in. with a mixture of lamp black and hematite; it is possible that this part of the work may be constructed of blocks and laid up in mortar. Special attention may be called to the following very desirable but often omitted requirement: "All exposed surfaces of finished and unfinished concrete shall be kept constantly moist by sprinkling with clean water at short intervals, unless otherwise directed during cold weather, or by covering with moistened burlap, or by such other means as shall be approved, and this moistening shall continue until the permanent covering is in place or until, in the opinion of the engineer, the concrete has sufficiently hardened."

The absence or presence of steel reinforcement and its nature is also a factor in classifying the concrete as above stated. The rods used are cold-twisted square bars of medium steel of ¼ to 1¼-in. size.

Bids were received for constructing these works on June 15, 1905, and the contract was awarded to Messrs. Westwater & Casey, of Columbus, at $524,209. The equipment of the filters was sublet to the Greer Filter Co., of Philadelphia.

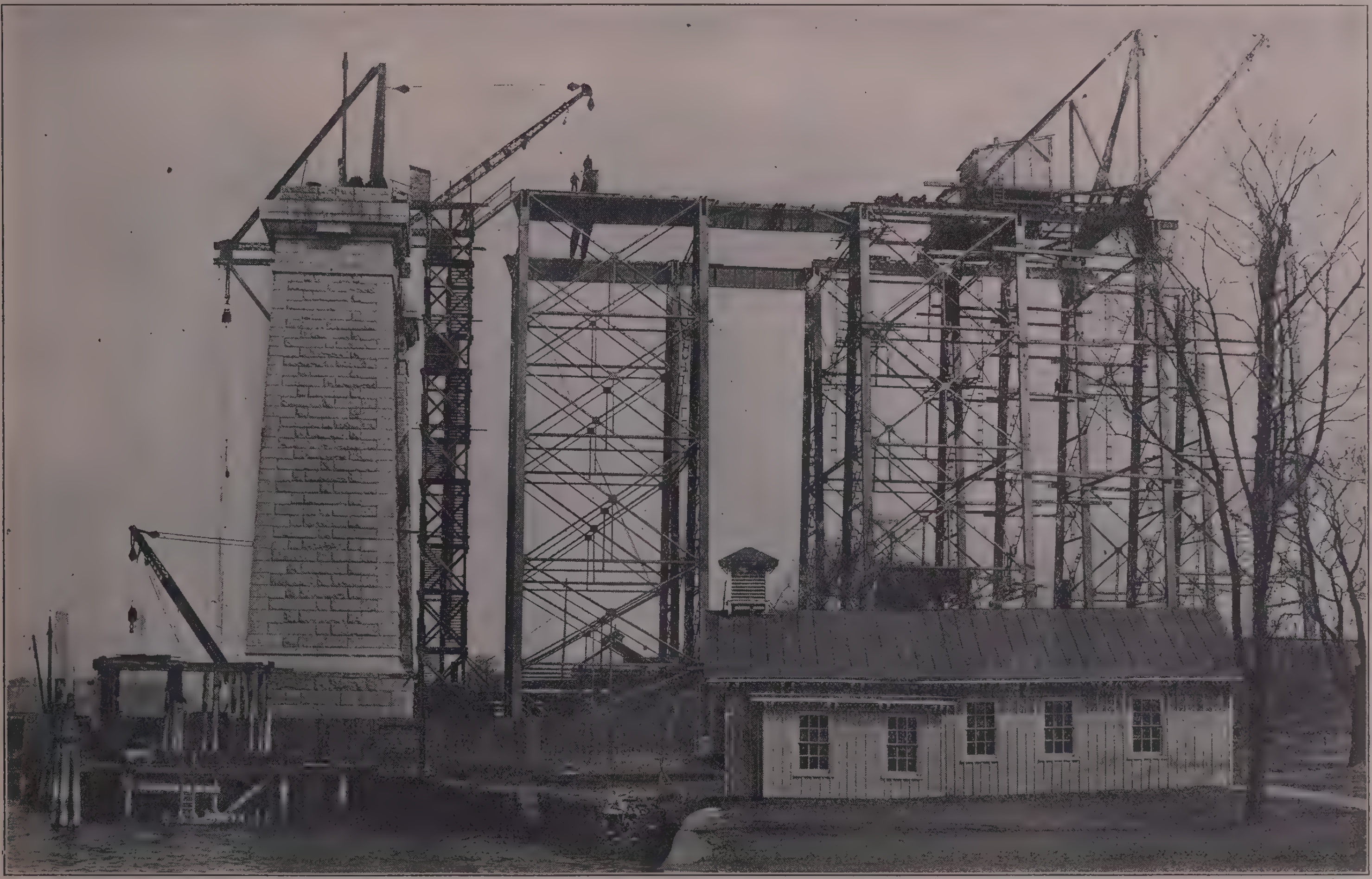
The works for the softening and filtration of the water supply of Columbus are under the direction of the Board of Public Service. Mr. Julian Griggs is chief engineer of the board, Mr. John H. Gregory is principal assistant engineer in charge of both design and construction, and Mr. George E. Howe is in immediate charge of the construction. Messrs. Rudolph Hering and George W. Fuller, of New York, have acted as consulting engineers of the work since its inception.

Raising a Sunken Steamer was recently accomplished by the aid of twenty Westinghouse air-brake pumps. These were placed along its deck so as to force air into thirteen of the air-tight compartments of the vessel. While the air was forced in the leaks in the hull were repaired by boiler makers as they were discovered, either by patching or with cement. When they were patched, all the pumps were set to work forcing air into the vessel and in this way enough water was displaced to raise her 4 ft., so she could be pulled off the shore. This method of raising vessels has advantages where the vessel's condition is such that enough compartments can be made water-tight to float her when they are filled with air.

Erection of Falsework and Pier Pedestals, Island Span, Blackwell's Island Bridge.

The direct preliminaries for the erection of the island span of the Blackwell's Island bridge at New York were commenced by the construction of the steel falsework about 120 ft. in height extending from pier II to pier III. It consists of 17 vertical transverse bents spaced from 30 to 40 ft. apart and located directly in the planes of the floor beams. Each bent is in reality double and is symmetrical above the center point. Each half consists of a pair of battered posts, each field spliced in four sections and braced by 6 horizontal transverse riveted struts, the panels between which are X-braced with light diagonal members. The two halves of the bent are braced together by three horizontal transverse members and by two panels of X-bracing.

At the center of the span there is a single bent of falsework between which and the adjoining bents there is no connection except by means of horizontal struts. The transverse bracing for this bent is the same as described above. By means of the special bracing as described, unobstructed spaces are provided for the hoisting of material to the distribution track above. All of the other bents are braced together in pairs with horizontal and diagonal struts corresponding to those in the transverse planes. This arrangement, therefore, provides a two-post falsework support under each panel point of each truss. The top of each of these separate supports has a pair of deep transverse plate girders web connected to the columns. Each transverse girder has a double web with heavy transverse brackets supporting a horizontal platform plate about 6 ft. square on which the pedestals and camber jacks are seated.


Erecting Steel Falsework for Island Span.

All field connections were made with ⅞-in. bolts so that the falsework can easily be taken down and re-erected for the anchor arms. In the latter case the superstructure is much lighter than for the island span and some of the towers will be strong enough to carry two panels of the trusses. Therefore intermediate panels will there be omitted and the tops of towers two panels apart will be connected by 8 lines of longitudinal plate girders 5½ ft. deep. The falsework columns have foundations composed of a grillage of 12x12-in. timber 10 ft. square and 15-in. I-beams on top of same.

The total weight of the falsework for the island span is about 1,700 tons. Its erection was commenced in January, 1905, and was accomplished in about 40 days, the work being handled very much like an ordinary viaduct which it resembled in many points. A 30-ton stiff-leg derrick, which was described in the previous article, was seated in the center of the top of pier II, and was rigged with a special boom 62 ft. long, which commanded from that position, the first two bents of the falsework and erected them. This derrick was operated by a hoisting engine on the ground on the land side of the pier. After the first two bents were erected I-beams were connected to their tops, forming a track on which the wooden falsework traveler was erected.

It consisted merely of a horizontal platform mounted on 6 double-flange wheels and carrying two stiff-leg derricks, one on each front corner. The platform was made with steel beams and channels and was anchored at the rear corners with yokes, each having four vertical 1¼-in. screw rods. It carried two 4-spool hoisting engines and each derrick had a 55-ft. 10-ton boom. The traveler erected one bent of falsework in advance of its position and then set longitudinal I-beams on it and on the last completed bent forming a runway track, on which it advanced to build the next bent, and so on.

Afterwards three plate girders 5½ ft. deep, borrowed from the anchor arm falsework, were placed on top of this falsework between bents 58 and 60, forming a platform on which one of the standard 65-ton stiff-leg derricks with a special 85-ft. boom was erected. It commanded the top of pier II and the first sub-panel of the permanent structure, and after removing the 30-ton derrick on pier II it was ready about April 1st to commence the erection of the cast steel pedestal and the members in the lower part of sub-panel 57-58.

The erection of the permanent steel superstructure commenced with the pedestals and transverse girders on pier II but a long delay was occasioned by the non-delivery by a sub-contractor of the massive cast steel pedestals required to begin the work. Each pedestal is about 17 ft. square and 10 ft. high, weighs about 260,000 lbs. and is made with four sections arranged in three vertical courses as illustrated in our issue of May 20, 1905. The first pedestal casting was received July 22 and the last casting for the first pedestal was received August 30. The south pedestal was immediately assembled in position by the 65-ton derrick on the top of falsework. The heaviest pedestal casting will be on pier I, and will weigh about 90,000 lbs.

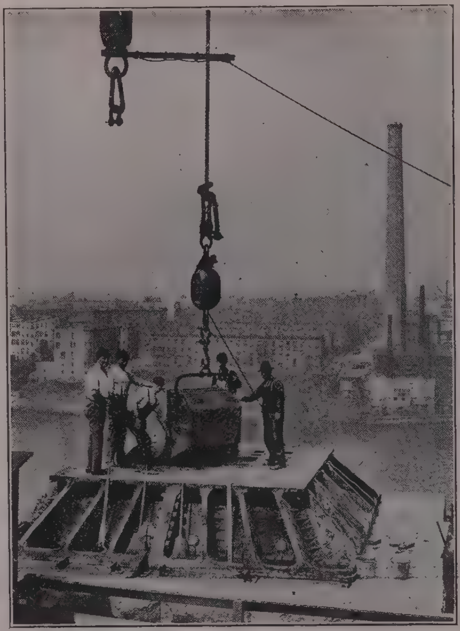
The heaviest casting in this pedestal weighs 72,000 lbs. and was lifted by a special device of 45-ton capacity which supported it with eight 2½-in. vertical bolts, about 4 ft. long, which passed through connection holes in the upper horizontal flange of the casting and took bearing with nuts underneath. The upper ends of these bolts passed between the double webs of a pair of transverse lifting girders 4 ft. long and 3 ft. apart and were secured to them by nut bearings. The lower flanges of the transverse girders were seated on the top flanges of a pair of longitudinal horizontal double-web girders 6 ft. long and 4 ft. apart, one of the 2½-in. vertical rods being each side of each longitudinal girder web. The longitudinal girders were suspended at their center points by pairs of eyebars for their upper pins engaging the ends of the double reinforced webs of a transverse evening girder 7½ ft. long. The evening girder had several sets of pin holes to provide for the different spacing of the longitudinal girders. It was connected to the hoisting tackle by a pair of short vertical plate links at the center points.

The granite beds on the top of the pier were dressed with great accuracy to a smooth level surface at the required elevation and the pedestal castings were seated on them with a very thin layer of Portland cement mortar and were lined in with a transit. Their positions were determined with absolute accuracy, no errors being allowed.

After assembling the south pedestal one-third of the horizontal transverse girder which receives the lateral system was connected to it. This girder, which was also illustrated May 20, 1905, is a massive member 10 ft. wide 3½ ft. deep and about 100 ft. long over all, with a cross sectional area of 450 sq. in. The top cover plate extends beyond the ends of the girder proper and forms fillers bolted between the top section of the pedestals and the lower section of the main tower posts. The girder was lifted in thirds by the derrick and hoisting device already described. As each course of the pedestal casting was assembled their hollow interior spaces were filled with concrete made 1 part Portland cement, 2 parts sand and 3 parts gravel, carefully worked in and spaded through holes left in the top flanges.

The last casting for the north pedestal was received Sept. 26, and that pedestal and the remainder of the transverse connecting girders were immediately erected in the same manner as those at the south side of the pier. On October 2, the derrick commenced the erection of the lower half of the first panel of the permanent substructure, subsequently erecting from the same position traveler No. 1, by which it was removed and the remainder of the lower half of the substructure was erected.

The bridge was designed and is being built under the direction of the Department of Bridges of New York. The contract for the manufacture and erection of the superstructure was awarded to Mr. J. V. W. Reynolds, vice-president, Mr. Fred W. Cohen, engineer of erection and Mr. L. N. Gross, general foreman of erection. The method and plan of erection has been described in The Engineering Record of March 4, 11 and 18, 1905, and Feb. 17, 1906.



Concreting Lower Course of Pedestal.

The Illinois Geological Commission has been organized under the supervision of Director Bain with a rapidity and thoroughness which is gratifying. The need of such a survey is well known to the engineers of the State, and it is interesting to observe the practical trend of the plans so far announced. Prof. C. W. Rolfe, Mr. Ross C. Purdy and Mr. H. B. Fox will investigate clay resources, Prof. S. W. Parr, Mr. F. F. Grout, Mr. F. B. Van Horn and the Director will study the coal fields, Prof. J. A. Udden, and Dr. Edward Bartow will examine ground water supplies, and Dr. U. S. Grant will have charge of the examinations of lead and zinc resources. Not all of these specialists will devote all their time to the Commission's work, but they will direct and co-operate in it, so that before long the State will have the comprehensive and accurate data it has long needed. The scientific geological work will presumably be carried along simultaneously with the more directly practical investigations, but the plan seems to be to make scientific investigations follow those for which industry and engineering are in urgent need, rather than to have the data of immediate usefulness form an incidental part of a prolonged and minute study of all geological conditions.

Plate and Can Systems of Refrigeration.

In a paper read before the American Society of Refrigerating Engineers, Mr. Edgar Penney made the following comments on the different systems of commercial ice manufacture:

Plate ice has its growth in thickness from one side only, and the exterior face is always in contact with free water. The ice formation grows from the freezing plate outward and thus enables certain undesirable properties of the water held in solution, or mechanically suspended, or other than mechanically fixed, to be separated and rejected by the slowly freezing water.

In can ice, the freezing proceeds from the four sides and the bottom, so that the impurities of the water are finally frozen in the center of the block of ice. The complications connected with the can system are the result of the effort to get rid of this center block of impurities in the ice. In making ice by the plate method, it is not necessary to distill the water, because filtering is sufficient. Water that will make clear ice on the plate system will leave undesirable impurities in a block of ice when frozen on the can system.

Boiling is the most practicable method of removing the impurities in water. By simply boiling the water in open air, some of the impurities will pass off, but to get the best results, it is necessary to evaporate the water and then distill it. To accomplish this, it is necessary to have boiler capacity sufficient to evaporate water of the same weight as the weight of ice produced plus the waste, which usually amounts to about 25 per cent.

Under an intelligent management, either of the systems will produce ice of good quality, but the can system depends upon a complicated arrangement of distilling and filtering apparatus. Plate ice possesses the desirable quality of keeping in storage equally as well as natural ice, without resort to mechanical refrigeration. If suitable well insulated ice houses are provided, the manufacture of plate ice can be carried on during the entire year. Can ice, from its lack of homogeneity due to the formation of miter-like corners, does not keep well.

Ice storage rooms for can ice must be maintained, by mechanical refrigeration, at a temperature equally as low as that of the freezing tank in which the cakes were frozen. Water, gas, electricity, or any cheap motive power, can be used for producing trade ice, but when distilled water is required, the can system must use steam. Sea and other waters containing mineral matter can be successfully frozen on the plate system, if a low rate of freezing is used, but it is difficult to handle such waters on the can system.

For producing ice 12 to 14 in. thick, the investment is greater in the plate system by 33 to 75 per cent. than in the can system. This extra cost is due to the large size of buildings required, to the cost of high pressure, compound condensing steam engines and power traveling cranes, and to the expensive construction of freezing tanks and cells, or, in other words, in the plate system, the highest type and most economical type of labor saving steam engines and machinery can be used with a resulting increase from the investment.

With the highest class special equipment, the plate system gives 14 lb. of ice to 1 of coal and with the average high grade equipment, 10.5 lb. of ice to 1 lb. of coal. The average can system uses about 1 lb. of coal to 6 lb. of ice. When the plant is arranged in a one-story structure, the plate system requires about twice as much ground for the building as the can system.

In installing a can system the initial cost is one-half that of the plate system, and for the same capacity the can system plant occupies half as much space as the plate system. At the same time it is possible to run the plate plant all the year round and to store the ice, thus doing the same amount of work with a plate plant that has only half the capacity of the can plant and doing it at the same cost.

Unless water or electric power can be obtained to drive a plate plant it is not policy to install such a plant, for the reason that the cost of maintenance of a plate plant is so much greater than that of a can plant. With the apparatus now commonly used in can plants, ice can be obtained that is sufficiently clear for all practical purposes.

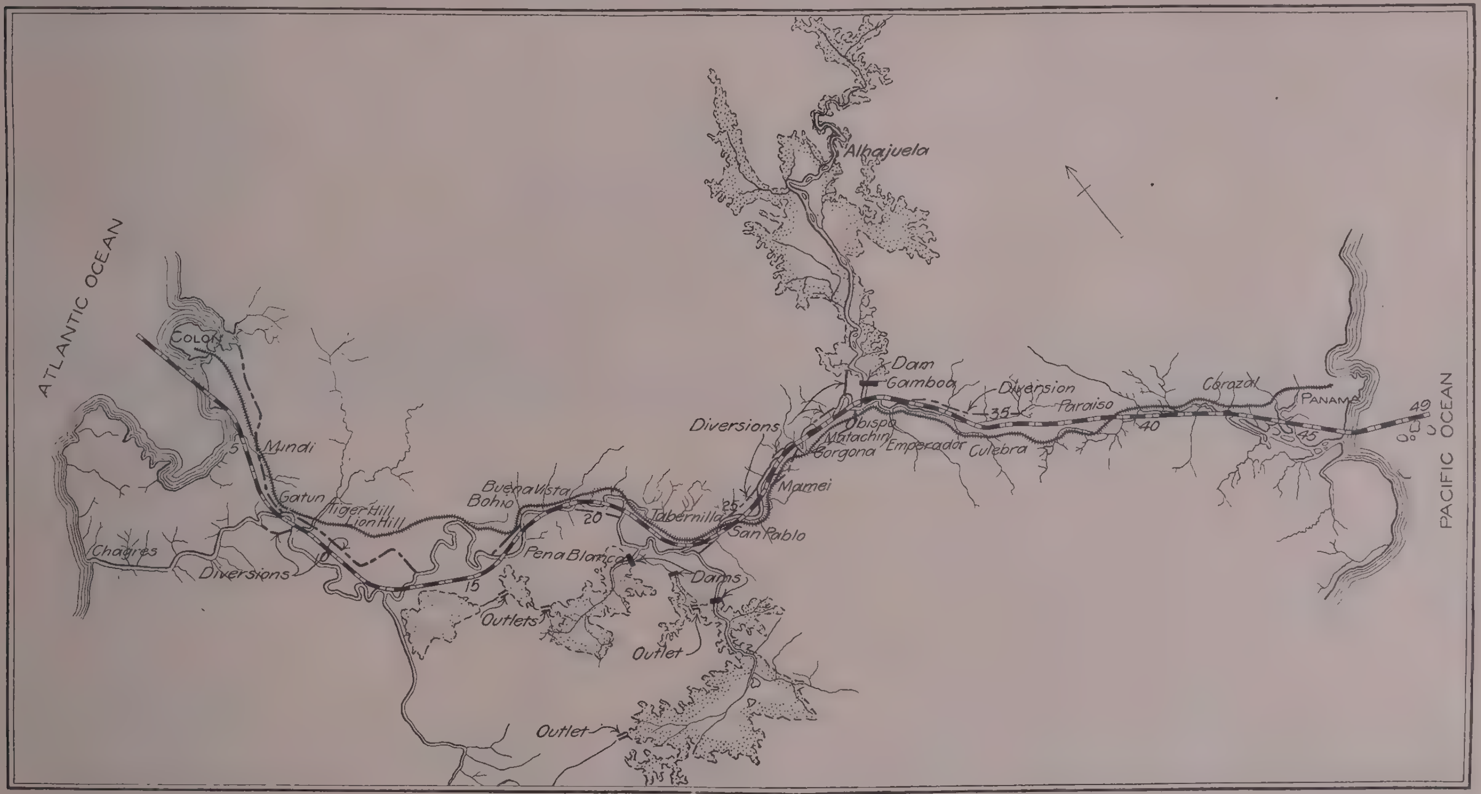
It is usual to allow fourteen 300-lb. cans to the ton where expansion coils are used, and where expansion coils are fed by the flooded system, twelve cans are amply sufficient. In the counter-current system, where the brine is cooled in separate compartments from that in which the ice is made, and the cans are made to travel towards the coldest brine, ten cans per ton of ice are sufficient. In plate and block systems it is usual to employ from 260 to 275 sq. ft. of freezing surface per ton of ice. The cost of these plants based on 50-tons capacity would be about as follows: Can system, $550 a ton; block system, $650 a ton; plate system, with direct expansion pipes, $800 a ton; and with the brine plate system, $1,000 a ton.

With water at 60° F. and with the best steaming coal, a good plate plant will produce about 10 tons of ice for a ton of coal, and a good can plant will produce about 7½ tons.

Producer Gas is used for heating and cooking in several places in Great Britain, notably at the Gloucester County Asylum, where this practice has been followed for 22 years, according to Mr. A. S. E. Ackermann. It has also been used for this purpose for about five years at the Walthamstow Isolation Hospital, where it is employed as fuel for gas engines driving lighting dynamos. The gas is not only used for warming the buildings, but also for heating the hot water supply. The kitchen furnishes meals for about eighty persons, and in the three years it has been in operation it has given entire satisfaction and no repairs have been required. Producer gas is also so employed in the works of Messrs. Ashmore, Benson, Pease & Co. at Stockton-on-Tees, the works of Messrs. Brunner, Mond & Co. at Winnington and the building of the Co-operative Society at Irlam.

THE REPORT OF THE BOARD OF CONSULTING ENGINEERS FOR THE PANAMA CANAL.

The most important document in the engineering history of the Panama Canal to date is probably the report of the Board of Consulting Engineers, consisting of Maj.-Gen. George W. Davis, chairman; Mr. Alfred Noble, chief engineer of the East River Division of the Pennsylvania, New York & Long Island R. R.; Mr. Wm. Barclay Parsons, until recently chief engineer of the New York Rapid Transit Railroad Commission; Prof. Wm. H. Burr, of Columbia University, consulting engineer of the Board of Water Supply of New York City; Brig.-Gen. Henry L. Abbot; Mr. Frederic P. Stearns, chief engineer of the Metropolitan Water and Sewerage Board; Mr. Joseph Ripley, general superintendent of St. Marys Falls Canal; Mr. Isham Randolph, chief engineer of the Sanitary District of Chicago; Mr. Wm. H. Hunter, chief engineer of the Manchester Ship Canal, nominated by the British government; Mr. Eugen Tincauzer, nominated by the German government; Mr. Adolph Guérard, nominated by the French government; Mr. E. Quellennec, consulting engineer of the Suez Canal Co.; Mr. J. W. Welcker, nominated by the Netherlands government. Capt. John C. Oakes, Corps of Engineers, General Staff, U. S. A., was appointed secretary of the Board by the President. The first meeting of the Board was on Sept. 1, 1905, and its report is dated Jan. 10, 1906.



Map of the Panama Canal by the Sea Level Route.

By order of the President there were submitted to the Board for its consideration "the various plans proposed to and by the Isthmian Canal Commission." These included a plan prepared by the old commission on isthmian routes, one prepared by the Technical Committee of the New Panama Canal Commission, three projects prepared by Mr. Lindon W. Bates, the more important results of recent surveys, a paper prepared by Mr. B. Bunau-Varilla on his proposed method of constructing the canal, a project by Major Cassius E. Gillette, Corps of Engineers, U. S. A., and a paper on the Gatun dam by Mr. C. D. Ward.

As a basis for all plans, the Board resolved by a vote of 11 to 2 that locks should be at least 1,000 ft. long, 100 ft. wide and 40 ft. deep. It decided unanimously that in order to make its estimates comparable with those of previous commissions, there should be added to the estimated cost of construction an allowance of 20 per cent. for administration, engineering and contingencies, but exclusive of interest during construction, sanitation, the expense of Zone government and collateral costs. The Board also decided not to attempt to make any estimate of cost of the lands to be flooded by the canal or lakes connected with it, on account of the impossibility of procuring reliable information on which to base such estimates. The Board points out, however, that such costs may assume large proportions, especially if lands near cities and villages should be required.

The Board determined by a vote of eight to five to adopt, for comparison with a sea-level canal, one with its summit level at El. 60 ft. It decided that there should be duplicate locks at Sosa, Pedro Miguel, Gatun and Bohio, and a dam at Gamboa for the regulation of the Chagres. This plan is not the most feasible for subsequent conversion to a sea-level canal, for the Board agreed as to the impracticability of converting a lock canal to one at sea level, in the immediate future, on account of the difficulty and danger of the operation and its excessive cost.

In regard to the time required to construct the two canals, the Board resolved, by a 7 to 6 vote: "That the Board declare in its report that the time of finishing the sea-level canal depends on many contingencies that cannot be definitely estimated in time; that under efficient management and not seriously affected by extraordinary and unforeseen difficulties, political obstructions or bad sanitation it may be regarded as feasible to complete the work in about twelve or thirteen years; that adverse conditions may lengthen that period, while favorable circumstances and continuous first-class direction may make it possible to shorten that period by one or two years." It was unanimously resolved in similar language that the canal with locks on the plans prepared by the Board may be constructed in ten to eleven years.

The Board finally passed the following resolution, Messrs. Davis, Parsons, Burr, Hunter, Guérard, Quellennec, Tincauzer and Welcker voting for it, and Messrs. Abbot, Noble, Stearns, Randolph and Ripley against it:

"Whereas, in the judgment of this Board, a sea-level canal is feasible, following a line with dimensions and such arrangements that the transit between the two oceans shall be secured in a permanent manner for all time under the best conditions for navigation and safety, for vessels of the largest tonnage and greatest draft now in use, or such as may be reasonably anticipated: Therefore,

"Resolved, That the Board adopt and recommend to the President of the United States, the plan of a sea-level canal with a depth of 40 ft., a width in rock of 200 ft., a minimum bottom width in earth of 150 ft., with a double tidal lock at Ancon, whose usable dimensions shall be 1,000 ft. in length and 100 ft. in width, and with a dam at Gamboa for the control of the Chagres River."

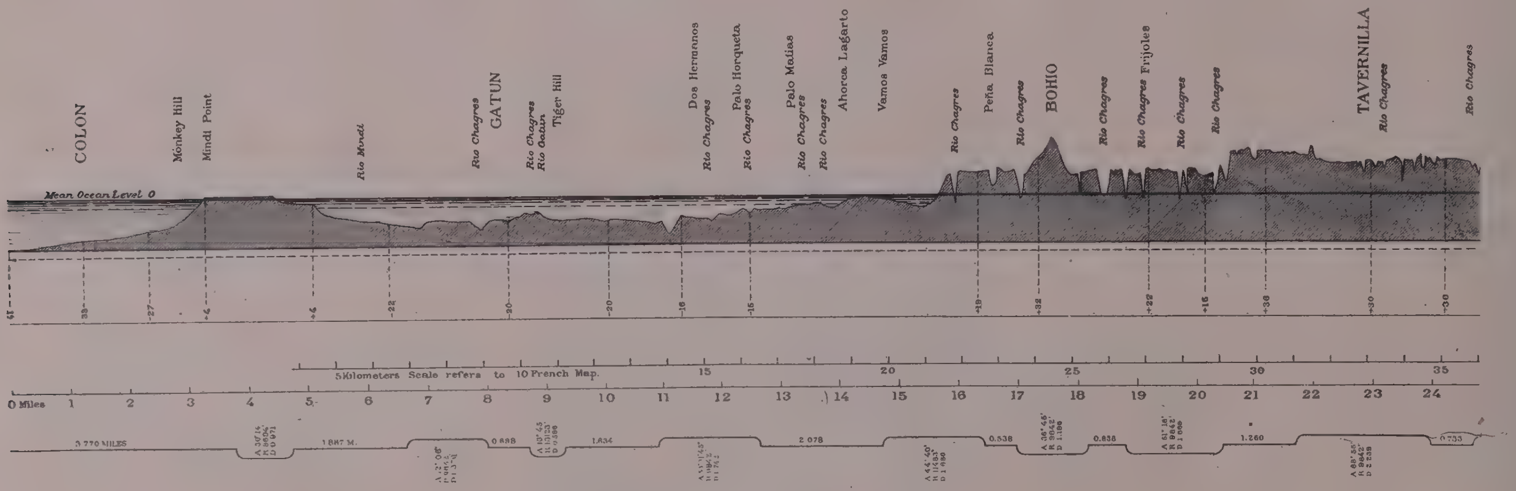
In accordance with this decision, the Board submitted a general plan for a sea-level canal, of which the essential features are described below:

ALIGNMENT AND DESCRIPTION.

The width of the Isthmus at Panama is less than at any other point where it is feasible to construct a canal open throughout between the oceans. The width, less than 36 miles in a straight line, is only five miles greater than at the narrowest place, San Blas, but an open cut is impracticable there. The summit on the Panama route, which was 333 ft. above the sea originally, is lower than at any other known point between the Arctic Ocean and the Straits of Magellan, Nicaragua only excepted, while at the latter place, by reason of the greater distance between the oceans, the volume of material to be removed to form a lock canal is much greater than at Panama, and a sea-level canal is obviously impossible.

Location.—The initial point of the axis of the canal is located in Limon Bay, at the beginning of the dredged entrance channel, where the depth of water is at least 40 ft. at low tide. From that point the axis of the dredged approach channel runs straight to near the southern limit of Limon Bay, where, near Mindi, a curve unites it with the center line of the canal, as partially completed by the old company. From Mindi the proposed line follows the partially excavated canal through the low marshy ground nearly to Bohio, a distance of 12 miles. The canal line first cuts the course of the Chagres River at Gatun, 7 miles from Colon, and then repeatedly cuts it from that point to Bohio. The excavation throughout this entire distance from the sea channel to Bohio can be made by dredging, but there is some hard clay to be removed.

After passing Bohio the ground rises gradually toward Panama and radically changes in character. A considerable quantity of rock must be removed at Bohio, and the same material is found in considerable quantities throughout almost the entire remaining distance to the shore of Panama Bay. The canal line from Bohio follows practically the general line of the Chagres River, cutting or coinciding with the bed of the river at many points, to Obispo, 14 miles from Bohio. The bed of the river at Bohio is practically at sea level, and about 50 ft. above sea level at Gamboa, near Obispo. While the surface of the ground is varied and broken, the ascent is gradual and nearly uniform to Obispo. The material to be excavated is clayey and sandy in large part, although rock in substantial quantities is found projecting above sea level at some points, mostly in the lower part of the proposed excavation. The excavations made by the old company along this portion of the route were generally shallow, although deeper at some points where hills exist, but constituting a nearly continuous surface cutting. That company excavated very little rock in this vicinity.



Profile of Northern Part of Sea Level Canal.

The general course of the canal from Colon to Obispo is southeast, and in part due south. Although there are several curves they are all of large radii, the shortest arc being 1.4 miles in length.

The vicinity of Obispo, about three-fourths of a mile only from Gamboa on the Chagres River, is a marked one in the alignment of the canal. At this point the valley of the Chagres, passing upstream, trends sharply to the northeast nearly at right angles to its course below Gamboa, but the canal line continues toward Panama. The waters of the Chagres escaping from the Gamboa reservoir through regulating sluices will enter the canal prism about three-fourths of a mile north of, or below, Obispo.

Continuing toward Panama the ground rises at a more rapid rate. At Obispo the great summit cut may be said to begin, as there is at that point a more abrupt rise in the surface of the ground and a correspondingly rapid increase in the depth of excavation. There is much rock to be removed from the canal prism at Obispo, and that material continues to form by far the greater part of the excavation through the divide to a point beyond Pedro Miguel, on the Pacific slope to the Cordillera. The deepest part of the summit cut at Culebra is about 5½ miles from Obispo. The maximum depth of excavation required for a sea-level canal will be about 373 ft. below the original surface where the axis cuts the saddle. The deepest part of the present cut, however, is about 160 ft. below the original surface, or about 213 ft. above the bottom of the excavated channel required by the sea-level plan. The length of the main part of the great summit cut is about 9 miles from Obispo to Pedro Miguel. The material to be removed is partly of indurated clay so hard as to be classed as soft rock, and partly of hard rock with a surface covering of clay.

The canal line reaches low marshy ground nearly at sea level at a point about two miles below Pedro Miguel. From that point to deep water in Panama Bay the location recommended by the Board is practically a straight line from a point a short distance from Miraflores through the Rio Grande swamp; but opposite Corozal a low ridge or spur from the eastern highland is crossed, in which ridge the borings show rock. Advantage is to be taken of this conformation to locate on the rock foundation a wide spillway with regulating sluices primarily for discharging into the Rio Grande and so into the Pacific a part of the Chagres flow at Gamboa coming through the Culebra, but the sluices may also be used to regulate and reduce the currents in the canal while the tidal lock is open.

The canal continues in a straight line through the swamp and through the saddle between Ancon and Sosa hills, where the tidal lock is to be placed, and thence to deep water off Isle Flamenco. From Miraflores to the lock the canal will be leveed, so as to prevent the tidal flow from entering it.

Navigation.—Experience in the navigation of maritime canals shows that the area of the west section of the prism must be at least four times that of the immersed section of the ship passing through it at a speed of 6 miles per hour. The smallest area of cross section of the canal prism, in rock excavation, exceeds 8,000 sq. ft. The dimensions adopted by the Board, therefore, will permit a speed of 6 miles per hour for the largest existing vessel using it, and of not less than 8 miles per hour for the average ship. For a ship of 90 ft. beam and 38 ft. draft a speed of 4 or 5 miles per hour might be considered sufficient.

These speeds will enable ships of the largest size to pass through the canal in 7 hours if the gates of the tidal lock at Panama are open, as they will be for more than half the time, or in 8 hours during high spring tides, when the tidal locks will be in use. The time of passage of the average ship will probably be between 5 and 6 hours with the gates of the tidal lock open, or one hour longer when the tidal lock is in use. For a ship of the exceptional size given the time of transit might reach 10 hours. The width adopted for the canal will be sufficient to allow two ordinary merchant steamers to pass each other on the line of the canal without stopping.

Length.—The entire length of the line between shore lines is a little over 40 miles, while the total distance, including harbor channels, is 49.35 miles. The total length of curves is 19.17 miles, leaving 30.18 miles of tangents.

Dams and Sluices.—At Gamboa there is to be located a dam, either of masonry or of earth and masonry combined, for the control of the Chagres, and at Corozal, sluices by which, during half the tide period when the level in the Pacific is lower than that in the Atlantic, water can be discharged from the canal into Panama Bay.

Cost.—The accompanying tabulation gives the total excavation as very carefully computed from the data supplied by the Isthmian Canal Commission, supplemented by data collected at the instance of the Board:

HARBORS.

Colon Harbor.—A first-class natural harbor is not found at either terminal of the canal, but good harbor accommodations can be created without unusual difficulty or extraordinary expense.

Limon Bay, on the easterly side of which is the city of Colon, must be the Caribbean terminal of the canal. It is a rectangular indentation of the low-lying coast, with a width of 2¾ miles and a length of a little more than 4 miles. It is shallow, freely open to the sea from the north, and but little less exposed to the northeast and northwest. The extreme range of tide seldom exceeds 2½ ft. except under the influence of high winds. The mean average is about 1½ ft.

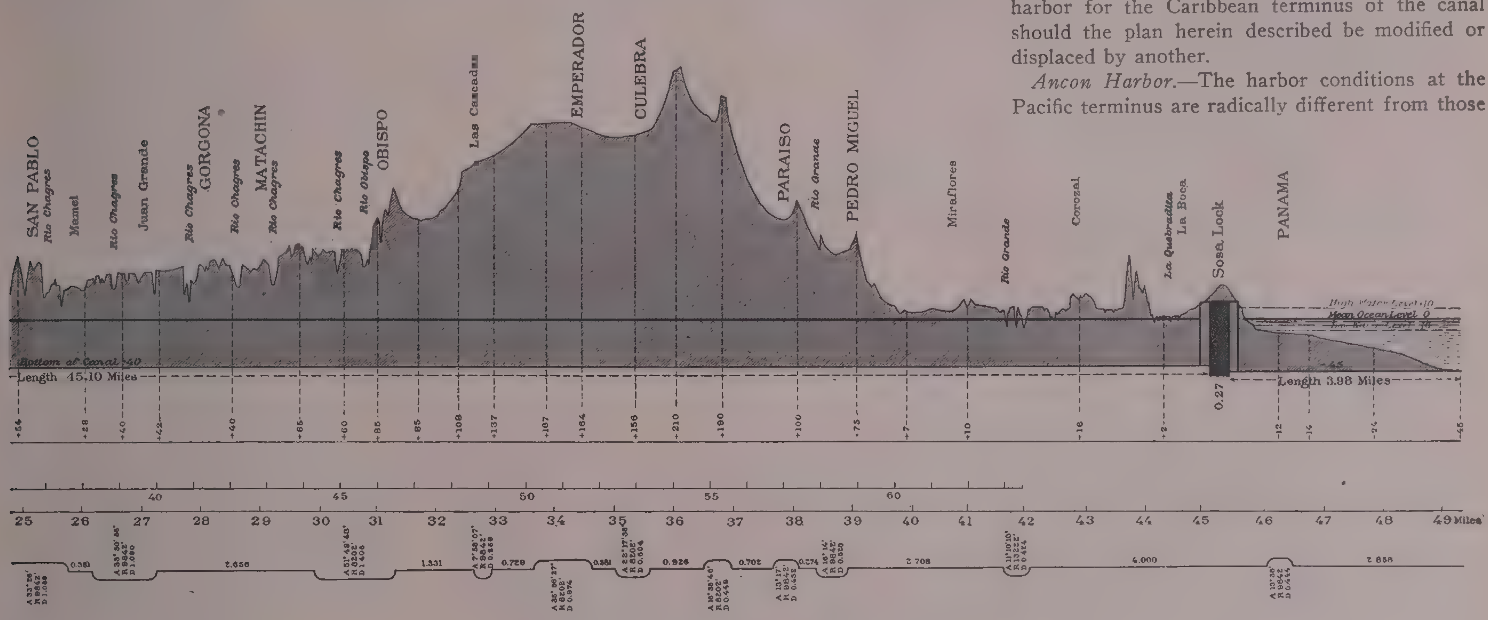
The depth of water at the entrance to the bay in its central portion is from 30 to 38 ft. opposite the water front of Colon. The southern half of the bay is so shallow as to be of no value for harbor purposes. The currents in the bay have little velocity. The greater part of the bottom of Limon Bay is soft. There is undoubtedly a decided movement of the material of the soft bottom in the easterly portions of the bay by storm waves, although the rarity of the storms prevents the aggregate of movement being very large.

Storms.—Limon Bay is open to the north, and northers blow directly into it. They occur, on the average, not more than three or four days

Estimate of Excavation of a Sea-Level Canal 40 Feet Deep.

Stations.	Classification.	Cu. yds.	Price.	Amount.
41-ft. contour to shore line of Limon Bay, 0 to mile 3.92	Earth	2,781,668	$0.15	$417,250.00
	Indurated clay	5,566	.70	3,896.20
	Coral	135,500	1.50	203,250.00
	Total	2,922,734		624,396,20
Shore line to Mindi, mile 3.92 to mile 5.49	Earth	7,695,885	.25	1,923,971.25
	Indurated clay	2,351,588	.70	1,646,111.60
	Total	10,047,473		3,570,082.85
Mindi to Bohio, mile 5.49 to mile 17.22	Earth	21,730,653	.25	5,432,663.25
	Rock above sea level	628,088	1.00	628,088.00
	Rock below sea level	2,198,643	2.50	5,497,107.50
	Total	24,557,584		11,557,858.75
Bohio to Obispo, mile 17.22 to mile 30.96	Earth	48,787,149	.40	19,514,859.60
	Rock above sea level	4,490,926	1.15	5,164,564.90
	Rock below sea level	7,396,362	2.50	18,491,905.00
	Total	60,674,437		43,171,829.50
Obispo to Pedro Miguel, mile 30.96 to mile 39.04	All material above + 10	93,697,408	.80	74,957,926.40
	All material below + 10	16,194,302	1.25	20,242,877.50
	Total	109,891,710		95,200,803.90
Pedro Miguel to Miraflores, mile 39.04 to mile 40.77	Earth above sea level	2,136,125	.40	854,450.00
	Earth below sea level	300,000	.25	75,000.00
	Rock above sea level	518,881	1.15	596,713.15
	Rock below sea level	2,474,138	2.50	6,185,345.00
	Total	5,429,144		7,711,508.15
Miraflores to south end of Sosa lock, mile 40.77 to mile 45.37	Earth	6,106,828	.40	2,444,731.20
	Rock nearly all below sea level	5,223,700	2.50	12,659,250.00
	Total	11,330,528		15,103,981.10
South end Sosa lock to 45-ft. contour in Pacific, mile 45.37 to mile 49.35	Earth	3,508,945	.15	536,341.75
	Rock	2,663,922	2.50	5,659,805.00
	Total	6,172,867		6,196,146.75
	Grand Total	231,026,477		$183,136,107.30

in the year and during some years not at all. During these storms the wind blows with high velocity, driving storm waves of great magnitude and force directly into the bay. At such times ships cannot lie at anchor nor be berthed alongside the piers on the waterfront without grave danger. Indeed, vessels unable to get away in time to escape such storms have been wrecked on the water front of Colon as well as at other points in the bay.



Profile of Southern Part of Sea Level Canal.

As ships may wish to enter the canal at any time, the terminal harbor must offer safe entrance to it any day in the year and under all conditions of weather. In view of the experience with northers ever since the harbor of Colon has been frequented by shipping, it is imperative that this terminal harbor should be so designed and constructed as to protect the dredged approach channel, both against the storm waves and the resulting currents which would otherwise tend to fill the channel. Without such ample protection it is practically certain that the dredged approach channel in the bay of Limon would be filled by sediment during one such norther, as was witnessed by three members of the Board. There should also be afforded ample anchorage ground within the protected harbor, with the requisite room for maneuvering.

Colon Entrance Channel.—To enable vessels to enter or leave the harbor at all times, even during severe northers, the channel should have the same direction as the winds during such storms, which are almost always from a point slightly west of north. A vessel entering or leaving this channel in a storm would therefore have the wind ahead or astern and without any wind abeam to complicate the navigation of the channel. It is for this reason that the Board has proposed a straight entrance channel nearly parallel to the Colon shore and united at its southerly end by a curve of large radius with the axis of the canal near Mindi.

Harbor Works.—After much consideration of all the conditions bearing upon the construction of a safe and commodious harbor, the Board provisionally adopted two converging breakwaters, which would inclose a harbor area nearly 9,000 ft. from the entrance and nearly 4,000 ft. wide for a distance of at least eight-tenths of a mile, within which the depth at low water would vary from 30 to 35 ft. Within the protected harbor a dredged entrance channel 500 ft. wide on the bottom and 40 ft. deep at low water would lead straight from the entrance between jetties to the canal entrance near the mouth of the Mindi.

At the same time, the inner harbor immediately south of Cristobal Point should be so completed as to afford on its easterly side the necessary coaling facilities, administration offices and other buildings required by the canal traffic. Vessels entering the outer or main harbor will anchor, if they desire to do so, arrange for payment of dues and their passage through the canal, secure such supplies and make such other communications with the port as may be necessary, then pass to the coaling station, if desired, or proceed directly into the canal.

The breakwaters may be constructed as mounds composed of suitable fragments of hard rock for their superstructures, or blocks of concrete, as may be considered most economical or desirable, but resting up on rubble substructures, which may be of softer material taken from the excavations or from other sources, as the actual construction of the work may make most convenient or economical. The type and cross section of these breakwaters and the general character of the structures would be similar to others which have been constructed on the Atlantic, Pacific and Gulf coasts of the United States, as at Delaware Bay, San Pedro and Galveston.

This harbor as designed, including the ports of Cristobal and Colon, will furnish sufficient accommodations for an indefinite period in the future for the greatest traffic which can now be anticipated for the canal. The Board does not set forth this plan as that which it would necessarily hold to in all details after a more prolonged study and consideration of all the circumstances affecting the construction of such a harbor, but it believes that the amount estimated as its costs is sufficient to cover the construction of a suitable harbor for the Caribbean terminus of the canal should the plan herein described be modified or displaced by another.

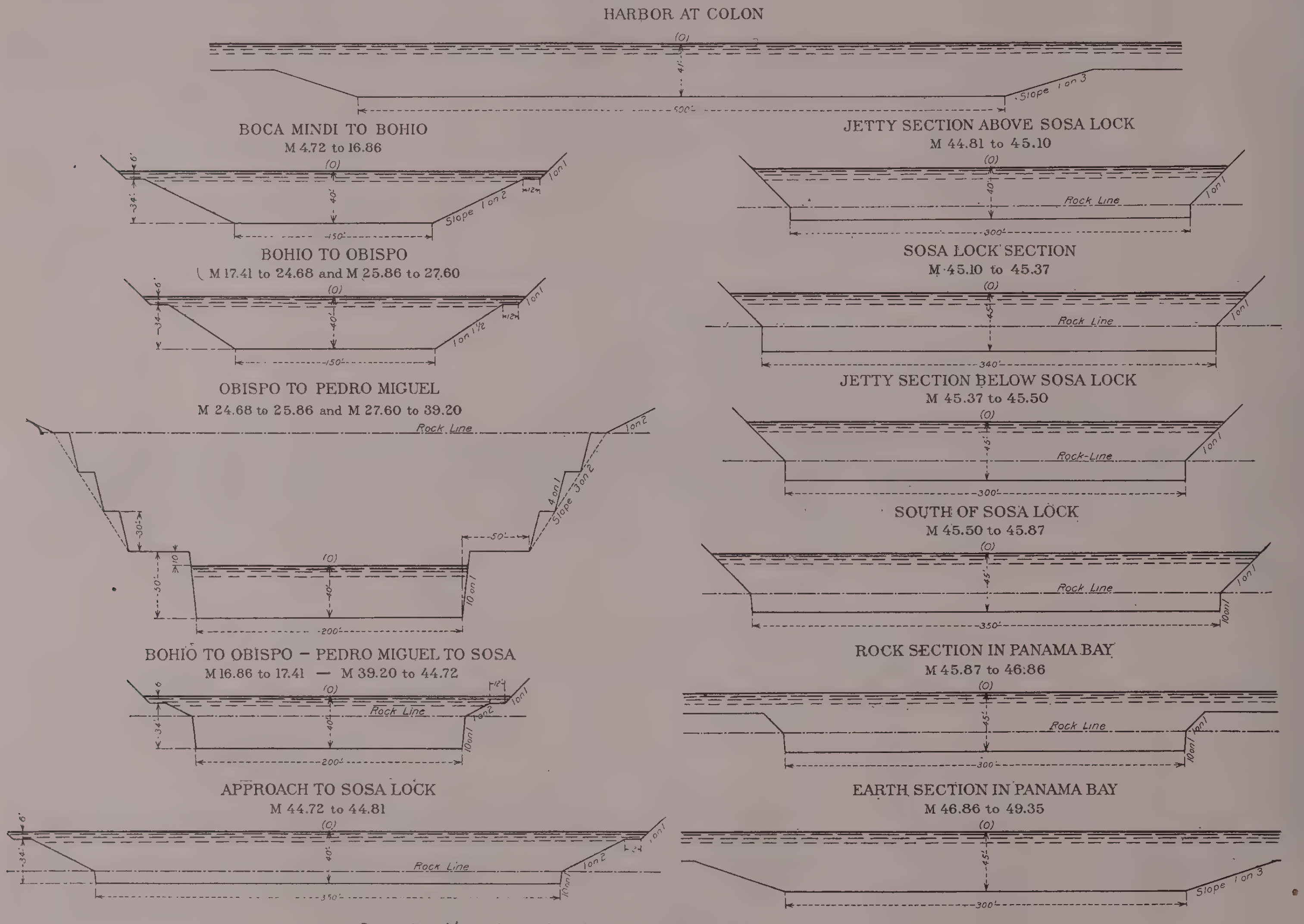
Ancon Harbor.—The harbor conditions at the Pacific terminus are radically different from those found at the Caribbean end, in that no storms ever occur of sufficient magnitude to disturb vessels anchored in the roadstead northerly of the islands of Perico and Naos, the usual anchorage, which is 3 miles by the present dredged channel to the entrance of the canal at La Boca. Owing to littoral currents from the west this channel requires the practically constant service of dredges in order to maintain a depth of 20 to 22 ft. At the present entrance of the canal, which is also the mouth of the Rio Grande estuary, there has been built a steel wharf 1,000 ft. long, carrying two railroad tracks and a loading platform. Mud and rock have been dredged over an area in front of it to make a turning basin sufficient for the present needs. The depth of water alongside and in the basin varies from 22 to 25 ft. at low water, but, like the entrance channel, must be frequently dredged to maintain this depth.

The tides in Panama Bay are of far greater range than those at Colon, although mean sea level is the same in both harbors. They are very regular. During spring tides the water surface may oscillate between 10 ft. above mean sea level to 10 below. During neap tides the range from high to low may not exceed 7.9 ft.

Ancon Entrance Channel.—If the present location of the Pacific end of the canal from Miraflores to La Boca should be retained it would be necessary to widen and deepen the channel sufficiently to meet the requirements of the ship canal now projected. Remembering that extremely low water may be as much as 10½ ft. below mean tide it is obvious that a much deeper excavation will be required to afford the prescribed minimum depth of 40 ft. in the harbor approach channel than will suffice at the Caribbean terminus of the canal. The location of the tidal lock will determine the distance inland to which this maximum depth of excavation must be carried.

The Board believes that a straight entrance possesses sufficient additional advantages to justify substantial increase in expenditure to obtain it. A new alignment, therefore, for the Pacific end of the canal and the dredged channel has been adopted, extending from a point between Corozal and Miraflores in a straight course to the new site of the tidal lock between Sosa and Ancon Hills, thence with a slight change in direction near the lock directly to deep water off the island of Flamenco. Rock outcrops between Ancon and Sosa hills and that vicinity afford a perfectly satisfactory foundation for this structure.

This relocation of the terminal portion of the canal line necessitates the excavation of a materially increased amount of hard rock, which has been included in the estimate of total cost, although as much submarine rock excavation in the vicinity of the islands has been avoided as possible. While there may be a difference of opinion as to the justification for such additional cost in securing a better entrance, there can be no doubt that the alignment adopted by the Board will result in easier and safer navigation for vessels entering the canal from the Pacific, and in much less cost for dredging to maintain it.



Cross Sections of Sea Level Canal at Different Points Along Route.

It is evident that the approach channel on this new location may be subject to shoaling by sand moved by the eastward littoral current, as is the present channel. The rock excavated from the new entrance should be deposited along its westerly side so as to form a low dike, completely isolating it from the Rio Grande estuary. This will in no way change the regimen of the latter or of the roadstead near the islands, but it will afford complete protection against the easterly drift of the sediment and thus prevent deposition in the channel. It is possible, though not anticipated, that it may be advisable to form a similar low dike on the easterly side of the channel, and there will be sufficient rock from the channel excavation for that purpose should it be desired.

Tidal Lock.—The question of the necessity of a tidal lock at the Panama end of the canal has been raised by engineers of repute, but the limited time available to the Board has not permitted the full consideration of this question which is desirable. It is probable that in the absence of a tidal lock the tidal currents during extreme spring oscillations would reach five miles per hour. While it might be possible to devise facilities which would permit ships of large size to enter or leave the canal during the existence of such currents, the Board has considered it advisable to contemplate and estimate for twin tidal locks located near Sosa Hill, even though the period during which they would be needed would probably be confined to a part of each spring tide.

The highest recently recorded range of spring tides which the Board has seen was 19 ft. 9 in. between extreme low and extreme high water, while from 1882 to 1887 the highest amplitude reported was 20.93 ft. With such tides for a brief period at dead low water, the water in the canal would be 10 ft. above that in the bay, while at extreme high water for a correspondingly short period the level of the water in the bay would be 10 ft. higher than that in the canal.

At the period of mean tide there would be no difference of level between the bay and the canal, so that during that period of the tide all the gates of the tidal lock could be open, leaving an unobstructed passage for vessels until the approach of the flood tide rendered it necessary for the gates to be closed until slack water would again be reached, and so on for each succeeding spring tide. During neap tides the range is so small that it will not be found necessary to bring the gates of the lock into use. Consequently, throughout the neap period of each tidal cycle a continuously open and unobstructed passage for traffic will be provided through the tidal locks.

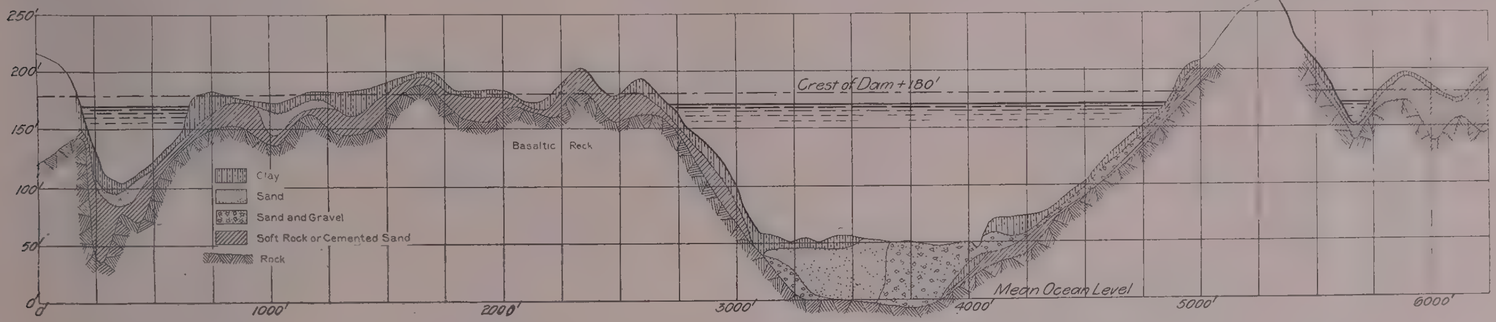
If the matter be put into figures for the sake of comparison, it will appear (1) that in the project for the sea-level canal one lock may be required at times at the Panama end of the waterway. For one-half of each tidal cycle of 14 days the gates may be operated to control a difference of head of an average height or depth of about 8 ft. for short periods on each tide, while for the remainder the difference of level between canal and ocean will be negligible. For the remaining half of each tidal cycle the gates will be out of operation and the locks will present an open and unobstructed channel, and (2) that in the project for the lock canal six locks or even more will be required for a canal with a summit level 80 to 90 ft. above the mean level of the sea; that these locks will have differences of level ranging from about 27 to 35 ft.; that their operation will be perennial, they will always be required, and consequently that the menace which they will present to the safe navigation of the canal by large steamers cannot be avoided and will be cumulative, i. e., must be multiplied by the number of lockages to which such vessels will be subjected during their passage through the canal.

CROSS-SECTIONS OF THE CANAL PRISM.

Depth.—The cross-sections of the prisms will vary with the character of the material excavated. Furthermore, the cross-section of the deeply dredged channels at the terminal harbors must obviously be different from those in the canal proper between the shore lines of the Isthmus.

In the judgment of the Board the depth of water in the canal prism and in both of the approach channels of the terminal harbors should not be less than 40 ft., except in the case of the channel in the bay of Panama, where at intervals that depth would not be found during short periods at extremely low spring tides. The depth of 40 ft. was therefore adopted by the Board as the standard minimum depth in the canal.

Width.—The standard bottom width in firm earth, including the dredged portions in soft material between the shore line of Limon Bay and Bohio, was fixed at 150 ft., the side slopes in the same material being taken at one vertical and two horizontal.



Profile On Line of Proposed Gamboa Dam Showing Depths to Rock.

In rock the bottom width was taken at 200 ft. with side slopes in the channel of ten vertical on one horizontal, i. e., practically vertical. The side slopes above water, as well as below, in firm earth between Bohio and Obispo and south of Paraiso were taken at the inclination of two vertical on three horizontal.

Slopes.—Some modifications of these standard sections were made by the Board in its estimates of quantities of material to be excavated in combined rock and earth sections between Bohio and Pedro Miguel, but not including the Culebra section. At many places throughout this distance the lower portions of those parts of the cuts above the water surface in the canal will be rock overlaid by earth or softer material. In the great summit cut the surface material overlying the rock for a considerable distance in the vicinity of Culebra Hill is clay, which, like all clay, slips easily when wet. When, however, this clay is drained, or otherwise protected from becoming saturated, it stands with satisfactory firmness and gives no trouble. Throughout these combined rock and earth slopes the rock is given a face slope in the estimates of ten vertical on one horizontal and the clay or other material above it one vertical on two horizontal. In the great Cubera cut, which really means the summit divide from Obispo to Pedro Miguel, a distance of 7¼ miles, a special form of section has been taken, although it includes the same elements of slope adopted for other portions of the cuts taken out in the dry. The same rock section for the prism of 200 ft. bottom width and with side slopes of ten vertical on one horizontal is carried up to an elevation of 10 ft. above mean tide, at which elevation there is provided a horizontal berm 50 ft. in width on each side of the canal prism. From the exterior limits of these berms benches are assumed for the purpose of estimate, each 30 ft. high, with a face slope of four vertical on one horizontal, the width of the bench at top being 12½ ft. These benches are carried to the upper limit of the rock portion of the cut. This makes the average or mean slope of the rock three vertical on two horizontal. The clay or other soft material overlying the rock is given the same slope of one vertical on two horizontal already described.

It is believed by the Board that the estimated volume based upon these side slopes is ample. It is probable that large portions of this summit cut, composed of harder rock than the indurated clay which forms the material classified as soft rock, will permit of faces having a slope of four vertical on one horizontal to be taken out much higher than 30 ft. It is further believed that there will be little sliding of these benches, assumed in the computations of quantities, so that the volume taken out of the great summit cut is much more likely to be less than that estimated than in excess of it, especially as a contingent margin has been added to all items of cost.

The materials classified as soft and hard rock have been exposed with surfaces fully as steep as four vertical on one horizontal ever since the old company ceased work in 1889, a period of 16 years. Furthermore, these slopes and others equally steep produced by the excavation made by the new French company have been under the personal observation of two members of the Board throughout the past six years, and under the daily observation of another member for over a year. During this time the effects of weathering have been small, soft rock as well as the hard having stood without sensible slipping or other deterioration. In fact, it is the result of extended experience with these steep faces both in Central America and on the Isthmus that the steeper the faces stand without crushing at their lower portions the less weathering and wash from the tropical rains will occur. It is therefore highly desirable to finish these slopes in as high benches and with face slopes as steep as practicable.

Very few slips of rock have occurred in the deepest portions of the Culebra cut since it was first opened. They are small and have been of such rare occurrence as not to affect the correctness of the preceding observations.

ESTIMATE OF COST.

The unit prices to be applied to the various items of work entering the completion of a sea-level canal have been formulated by the Board after most careful deliberation upon all the conditions affecting the actual prosecution of the work, including climatic effects, inefficiency of available labor, the distance of centers of supplies, the present condition of the various incomplete excavations, the general experience of the Isthmian Canal Commission since its creation, and other influences peculiar to the circumstances which will surround the execution of work in the field to its completion. It has been the intention of the Board to make these prices liberal, so as to remove as far as possible any probability of the ultimate cost of the work being greater than that estimated, and it is believed that they are sufficiently liberal to accomplish that purpose. It will be observed that they pertain to methods and material which have been well tried in engineering construction and do not rest upon anything of an experimental character, as it is the judgment of the Board that nothing should be included in the proposed plan other than that which has been justified by engineering experience with work as nearly similar to that contemplated in this project as possible.

The Board has taken account of and given due weight to the fact that vast improvements in mechanical excavating devices have, in the past few years, been made and their effectiveness demonstrated. The Board also believes that other improvements specially applicable at Panama will be developed and used as the work progresses, as was the case during the making of the Suez and the Chicago Drainage canals, and that these improvements will result in large economies and show that the unit prices are much too large; but in fixing these units account has been taken of nothing which has not been tested and justified in actual practice.

Applying the unit prices adopted to the quantities—a tabulation of the main items with a grouping of the smaller items—the following estimate of cost results:

Jetties in Limon Bay........................	$5,000,000
Excavation and dredging in earth, rock, etc., throughout the canal	183,136,000
Completion of river diversions, formation of dams across tributary streams, regulation of rivers which flow into the canal, etc......	3,500,000
Dam across Chagres Valley at Gamboa, with flood sluices, etc........................	6,000,000
Spillway, with flood sluices, near La Boca....	920,000
Twin tidal locks in the Ancon-Sosa saddle....	6,000,000
Leading jetties above and below locks........	795,000
Relaying track of Panama Railroad..........	500,000
	205,851,000
20 per cent. for contingencies, administration and engineering	41,170.200
Total	$247,021,200

The Board is confident that the Panama Canal can be constructed and completed under the plans set forth and recommended in this report within the preceding total sum of $247,021,200.

There are certain items of cost, such as construction of military defenses, naval stations, government of the Canal Zone, sanitation, lighthouses, buoying, lighting, and the provision of tugs, lighters, derricks, dredges, scows, etc., which have not been included. They are common to any type of canal. It was not understood to be the desire of the President that the Board should take into account anything that did not relate to the engineering features of the canal construction, but there is no doubt, in the opinion of the Board, that the expense of maintenance of a sea-level canal will be very much less than for a canal requiring lift locks.

Assuming that the total cost of the Panama Canal, including construction, payments to the French company for the property and franchise, to the Panama Republic for the rights conveyed, the cost of the Zone government until the canal is open, and other collateral costs, the total possibly reaching $333,000,000, the interest charge on this sum at three per cent. would reach $10,000,000. That such an investment would be a safe one from a commercial standpoint is indicated by the fact that the interest and dividends paid to the owners of the Suez Canal last year reached the total of $17,000,000, after paying all expenses of maintenance and operation, also the cost of the extensive enlargements and deepenings which are continually in progress.

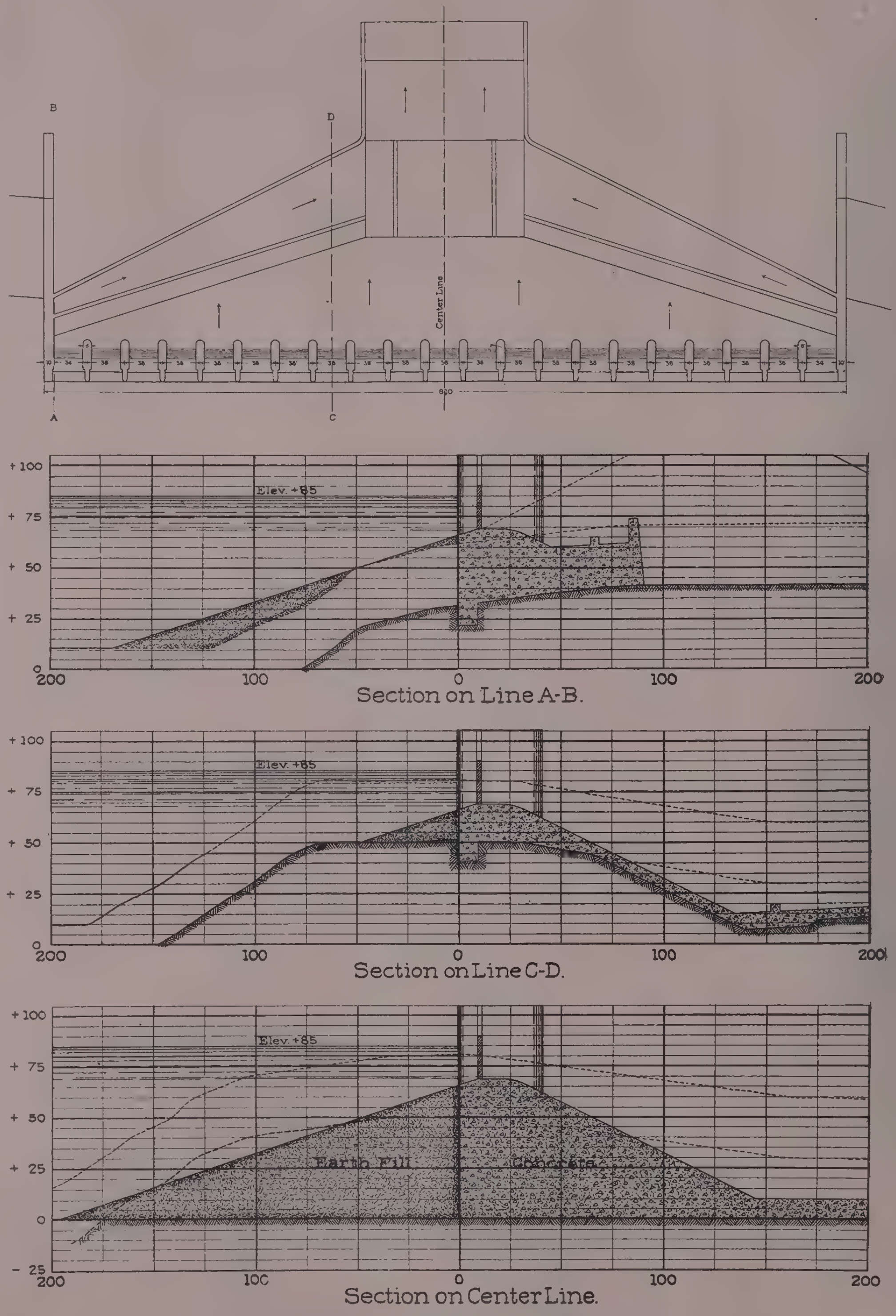
Estimate of Time.

The time required for the construction of a ship canal across the Isthmus is one of the main elements of the whole subject. If the execution of the work in accordance with any one plan could be completed within a reasonable time while the execution of the work under another plan of equal merit could be realized within a less time, it is clear that the latter plan should be adopted. If, however, there are two plans, both feasible and each involving an amount of work which can be accomplished within a reasonable period, it is clear that the execution of that plan requiring the longer period may be justifiable if the advantages thereby gained are sufficient, or more than sufficient, to compensate for the delay. If the work required under the less desirable plan can be finished within ten or eleven years while that under the more desirable plan would require but two years longer, the Board believes the small delay in the passage of the first vessel through the waterway might easily be neglected in comparison with the advantages secured under the better plan. It is necessary, therefore, to weigh carefully the significance of the time elements in reaching a conclusion as to the plan of canal to be adopted. In weighing these elements it is further necessary to consider that in the execution of the many locks and dams required for the lock canal, accidents during construction which would defer the opening of the waterway are more likely to take place than in the simpler works of the sea-level canal.

The time required to complete the construction of one or more of the main features of the plan controls the time required for the completion of the entire work, for the obvious reason that the various smaller features may be attacked and completed in detail in less time than would be required for the main or controlling ones. Under well-balanced administration of the work, therefore, the entire canal should be completed when the part requiring longest time is finished. As affecting the question of time for completion, and in marked degree that of cost also, there are two features of the sea-level plan which are of great moment: One is the excavation of the channel through the great divide, amounting to about 110,000,000 cu. yd. in a length of about seven miles, and the other the construction of the tidal lock near Ancon-Sosa, having a usable length of 1,000 ft. and width of 100 ft., with a maximum lift above mean sea level of 10 ft., this structure requiring over 600,000 cu. yd. of concrete and other masonry. These two features have received an extended and careful study.

Tidal Lock.—Inasmuch as hard rock outcrops in the immediate vicinity of the tidal lock site near Sosa Hill the amount of excavation required to secure a suitable foundation is not large and it can be expeditiously completed. The most serious part of this particular problem is to secure and assemble at the site the requisite cement, sand, gravel, or broken and other stone, and the plant required to mix and put in place the great mass of concrete and granite for the masonry portion of the lock. The gates as planned would be of steel, and each leaf would weigh about 275 tons. Their construction, shipment to the Isthmus, and erection in the locks would probably require a period of nearly two years. The Board has estimated that the time required for placement of the concrete and stonework would be four years after the excavation had been completed. It is therefore reasonable to estimate that the entire twin-lock construction, including excavation, concreting, erecting gates, and installing machinery, will require a period of not more than eight years. In estimating the time required it must be remembered that inasmuch as the change of level may be in both directions, up or down, to accommodate extreme high and low stages of tide, two sets of gates will be required in each of the twin locks. The total length of the structure will be not far from 1,300 ft., exclusive of the approach works. While these locks are great structures the lifts are comparatively small.

Gamboa Dam.—It may be suggested that the Gamboa dam, built to the height of 180 ft. above the rock in the deepest place, is also a great controlling factor as respects time, but the Board does not indorse such an opinion. If the dam be entirely of masonry, and allowing amply for interruptions by freshets or floods, the structure can be easily completed in less time than the tidal locks.



Section on Line A-B.

Section on Line C-D.

Section on Center Line.

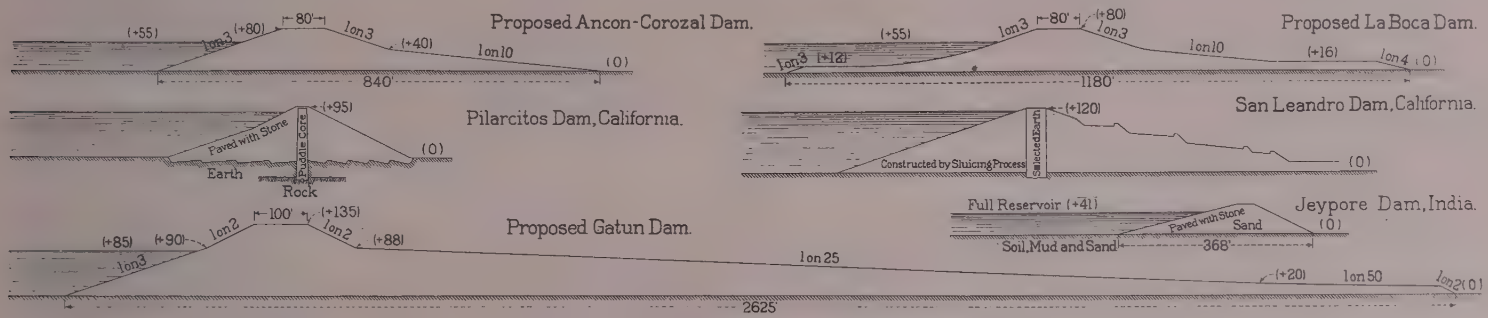
Plan and Sections of Regulating Works at Catun Dam.

Culebra Cut.—The excavation of 110,000,000 cu. yd. probably can not be completed in the seven miles of summit cutting within the period of eight years which are estimated to be requisite for the construction of the tidal locks. The excavation at the summit may therefore be considered as the controlling element in the time required to build a sea-level canal. The work in this cut is unprecedented. Great excavations for similar purposes have been made in the Chicago Drainage Canal, at the Corinth Canal in Greece, and in the Manchester Ship Canal. The maximum annual excavations, however, in these works have been

12,500,000, 2,500,000, and 12,000,000 cu. yd., respectively, but in no case was it all steam-shovel work, as it probably will be in the divide cut at Panama. The maximum depth at the Culebra cut from the original surface to the bottom of the canal will be 373 ft. and from the present surface 208 ft. The maximum depth of cut in the Corinth Canal was 286 ft., but no other excavation in recent years approaches in depth that proposed at Panama.

The time required to remove this great mass of material, by far the greater part being soft and hard rock, will depend greatly upon the efficiency of the method of operation and the organization of force and plant, all of which must be ultimately the result of most careful consideration of all the elements, including those of climate and character of labor available. It is clear that for the best results the greatest possible amount of work must be done by mechanical appliances and the least possible by manual labor. It is equally clear that the methods of conducting the work, including the control of the plant and force, must be such as will be subject to a minimum of climatic interference and effects of rainfall in the rainy seasons. All parts of the cut must be completely drained, so that the effects of rainfall and springs on the material to be moved may be reduced to the lowest limit.

Steam Shovels.—In considering this part of the Board's work it has taken full evidence regarding this great excavation from not only the present and former chief engineers of the Isthmian Canal Commission, but also from the division and resident engineers who have had the direct charge of the work. The records and plans of the French engineers and committees have been diligently studied. It appears safe to estimate from this evidence that from 80 to 100 steam shovels of the most effective type now in use on the Isthmus can be efficiently employed continually on this work after complete organization. It will require from two to two and a half years to install and put in operation this excavating plant. The independent studies by the Board of the arrangement of railroad tracks and of complete systems of attack at both ends of this summit cut completely confirm the conservatism of the evidence before it. It is as clearly demonstrable as any estimate of rate of progress and time for the completion of any great engineering work can be that after the full installation of plant not less than 100 steam shovels may be continuously engaged between Obispo and Pedro Miguel until the amount of work remaining to be done becomes too small to afford space for the operation of the whole plant.



Comparative Sections of Large Earth Dams.

Work Trains.—The Board recognizes that the removal of the material in the summit cut is in reality a problem of transportation. It is a comparatively simple matter to excavate the material within a much shorter time than that allowed for the work, even on the supposition that all of it except the clay near the surface must be shattered by preliminary blasting. The whole difficulty attending this part of the construction of the canal is attached to the removal of the material from the shovels or other excavators to the spoil banks. This problem of transportation is in reality the substance of the problem of building the transisthmian canal and, in treating this part of the project, the Board realizes and has considered the large amount of railroad track and the extensive transportation organization required for the disposition of the waste material. It is probable, as has been estimated, that not less than three miles of standard track will be required for each shovel employed, making a total of 300 miles of trackage for 100 shovels.

If it be assumed that 100 shovels are available for continuous work, there being a sufficient surplus above that number undergoing repairs whenever necessary to maintain the working complement, it can be demonstrated that as much as 20,000,000 cu. yd. of material classed as rock may be annually removed from the summit cut. This estimate is based upon an average number of working days of not more than 20 per month throughout the year, which is an under-estimate on the basis of the experience of the French companies and of that which has accrued since American occupation began, in May, 1904. In this estimate the capacity of one shovel is taken as materially less than would be justified by the actual operations of steam shovels in the Culebra cut during the past year, both in wet and dry seasons. Furthermore, it has been supposed that the working day is to be but eight hours long and that one shift only of laborers would be employed per day, whereas it is perfectly feasible to work two shifts in twenty-four hours during the greater part of the year and possibly during the entire year. Using these estimates for the period of what may be assumed to be the maximum annual output in the Culebra cut, and allowing at least two and a half years to attain this maximum rate at the beginning of the work and a period of not less than three years for a decreasing output in the more contracted space in the lower portions of the cut during the closing period of operations, it is found that the entire quantity of 110,000,000 cu. yd. of material in the divide can be removed within ten years.

Although the preceding estimate of time has been based upon ample allowances for the effect of the rainy seasons, for the low grade of labor available on the Isthmus, and for climatic conditions in general, the Board has added about 25 per cent. to it for other contingent causes of delay, either similar to those already provided for or of any other character. It is therefore the judgment of the Board that a ship canal on the sea-level plan outlined in this report can be completed within a period of time not exceeding twelve or thirteen years.

IMPORTANT CONSIDERATIONS.

The vastness of the interests to be served by the canal, many of which interests now wait for their development on the construction of the waterway, demands that the canal shall, when opened for traffic, be of the type which will most perfectly fulfill the purposes which the waterway is intended to accomplish.

Safe Navigation.—First and foremost it is essential that the Panama Canal shall present not merely a means of interoceanic navigation—it may be said that any type of canal would enable vessels to pass from ocean to ocean—but a means of *safe* and *uninterrupted* navigation, on which no special hazards will be encountered by and no vexatious delays will be occasioned to the vessels which will traverse it. It is therefore evident that the canal ought to be formed in such manner that the course thereof shall be free from all unnecessary obstructions, and that no obstacles should be interposed in that course, whether temporary or permanent, which would by their very nature be an occasion of peril and of detention to passing vessels, and more particularly to vessels of the great size which the Panama Canal is (in accordance with the provisions of the law of Congress) designed to accommodate.

The Board is of opinion that this consideration should be of determinative force in respect to the type of canal to be adopted, and that it should lead to rejection of all proposed plans in which lift locks, whether few or many, form the principal or dominating features, and consequently to the acceptance of the sea-level plan as the only one giving reasonable assurance of safe and uninterrupted navigation.

It is not suggested that a maritime canal with locks forming the essential feature is an inherently unsafe system of navigation, for experience has not only demonstrated the contrary, but that the matter is one of degree. A navigation with locks of small size capable of passing the ordinary commercial steamers may be made reasonably safe, while a maritime waterway with locks of the dimensions which the Board has considered to be necessary in order to meet the requirements of the Spooner Act might be and is thought to be so unsafe for the passage of the great seagoing vessels contemplated by that act as to be altogether beyond the limit of prudent design for safe operation and administrative efficiency.

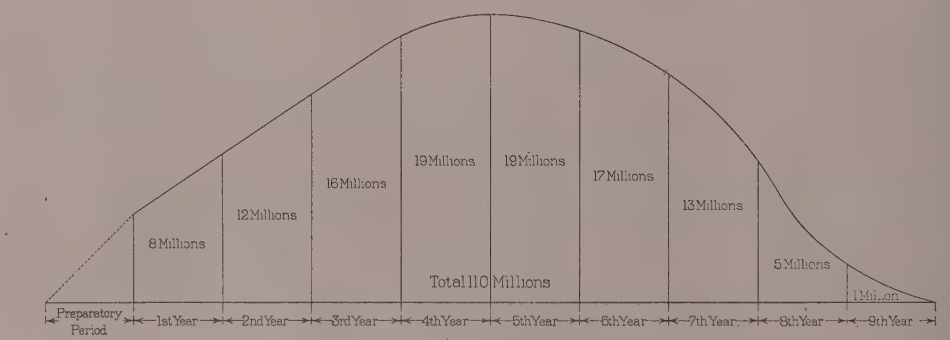
Accidents in Canals.—In the course of the proceedings of the Board it transpired that during the last nine years three accidents arising from collisions between steamers in transit and the lock gates, and resulting in each case in dangerous damage to these gates, occurred in the St. Marys Falls Canal; and also that three accidents arising from the same cause and having the same result occurred in the Manchester Ship Canal in England. Several of these accidents were so serious that disastrous consequences were escaped by a narrow margin only. It is practically certain that if the locks upon which these accidents took place had been of the dimensions and had controlled the great differences of level contemplated for the locks of the Panama Canal, not merely serious accidents, but disasters would have followed in perhaps all these cases, throwing the whole canal out of operation for a period which cannot be estimated, and also wrecking the vessels in the path of the resulting flood, while the cost required to repair the damages is not within the limits of reasonable computation. It is the unqualified judgment of the Board that the United States Government should not construct an interoceanic waterway to accommodate the commerce of the world exposed to hazards of this sort. These conditions become even more serious when it is contemplated that this canal is to be used for strategic purposes, and therefore for the interoceanic transit of vessels of war of the United States Navy.

Lock Canal Navigation.—As there is no maritime canal in the United States or about its borders it is natural to regard the navigation of the St. Marys Falls Canal as exhibiting conditions practically parallel to those which would exist in the Panama Canal, but inferences drawn upon such a basis may be greatly misleading. The lock in that caanl has been so successfully operated and its administration has exhibited such gratifying results that there is danger of forgetting that it is located in an environment of a highly special character. It is now a marked feature of the navigation route of the Great Lakes. The masters of the vessels passing this canal and lock are therefore familiar not only with every detail of the short canal in which the lock is located and of the lock itself, but also of every circumstance of its operation. They pass to and fro with their ships every two or three weeks during the period of navigation, so that the vessels which the lock serves are almost fixed features of a daily routine from which there is little or no variation. Entrance to and exit from the lock becomes by constant familiarity a routine performance in which constant repetition leads to a degree of skill and safety which can never be attained in a maritime waterway like that of the Panama Canal, serving the commerce of the world, carried in vessels whose masters would come in contact with the physical conditions surrounding the locks and the regulations governing their operation at rare intervals only, and whose crews would be absolutely strange to every feature of this canal service. Under such circumstances any variation from the simplest and plainest conditions of navigation would necessarily be a source of grave danger and likely to lead to serious accident. Again, the canal navigation at Sault Ste. Marie is closed by ice for three or four months each year. Then the locks are or can be pumped out, the gates and all other mechanism examined and repaired or replaced; but there will be no such annual period of idleness for similar overhauling at Panama.

It may be argued that the objections to the employment of lift locks apply also to the sea-level plan in which the construction of tidal locks at or near the Pacific terminus is a feature. It may be conceded that the argument is at first sight a fair one and that due weight should be given to it; but while it is clear in any case that one obstruction in the course of a maritime highway would be preferable to six or eight, the difference between the functions of any lift lock in the lock canal proposal and those of the tidal locks in the sea-level plan should be clear to any impartial critic. The tidal lock is for regulating purposes only, and the reason for its introduction is due to the natural circumstances which exist, there being practically no tidal range in the bay of Limon, at the Atlantic end of the canal, while in the bay of Panama, at the Pacific terminus, the range at high spring tides is more than 20 ft.

Lake Navigation.—Much has been said in the projects submitted to the Board about the advantages of lake navigation in the great reservoirs or lakes which it has been proposed to create by dams across the Chagres on the one side of the Isthmus and across the estuary of the Rio Grande on the other. Extended experience in the navigation of maritime canals on the continent of Europe and in Great Britain has shown that this advantage is largely imaginary, for it has been found in such canals, with prisms of much less dimensions than those recommended for this route, that steamers of the largest size which they can accommodate may steam through them at speeds of about six miles per hour without any real difficulty or danger. Such is the case in the Suez Canal and the Manchester Ship Canal. As a matter of fact, throughout the greater part of the Panama Canal traversing the proposed lakes the actual channels would have submerged banks, necessitating buoys, and within which the speed of vessels would not greatly exceed that possible in the sea-level canal.

Time of Locking.—It must also be observed in making a comparative consideration of the lock and sea-level types of canal that the locks in the former constitute a restriction or limit to the capacity for traffic of the waterway in which they are found, i. e., they are in a substantial measure obstructions to navigation. There is a limit to the number of lockages per day which may be made, perhaps not exceeding ten per lock or twenty per pair in any of the lock plans hitherto considered. The maintenance and operation of locks is also costly. If of such great dimensions as those considered necessary by the Board under the Spooner Act, they require the installation, maintenance and operation of an extensive power plant for the working of the gates. It is not easy to estimate what the annual cost of maintenance, including renewals and operation, of these would be, but, using the estimates of the Isthmian Canal Commission of 1899-1901, it is probable that the annual cost of operation of the six locks contemplated in the projects brought before the Board would be about $525,000. This annual charge capitalized at three per cent. would make a sum of $17,500,000 to be added to the cost of the lock canal. The corresponding item in the sea-level plan would be the capitalized annual cost of operating the tidal locks near Panama.



Note: Unit basis of calculation of curve-1 steam shovel @ 800 cubic yards per day
working for 240 days per annum
equals 192,000 cubic yards per annum.

Diagrams of Yearly Excavation to Complete Culebra Cut under Ten Years.

The comparative ease and economy of enlarging the prism of the sea-level canal to accommodate any additional demands of the future must be given the weight which properly belongs to it. The operations which have already been conducted so extensively in enlarging the prisms of the Suez and Manchester Ship Canals, and which are now about to be undertaken at the Kaiser Wilhelm Canal at Kiel, show that such operations may be required. The facility with which work of that character may be done in a sea-level waterway where there are no lock structures constitutes a material advantage.

Did a canal now exist of the widths proposed, but limited in depths to 35 ft., it would accommodate all existing shipping. By restricting the depths in the prisms (but not in the locks), as suggested but not recommended, the channel could probably be opened in a year or two less than if constructed at first to full depth, and the saving in cost would amount to about $17,000,000. When it should be decided to take out the other 5 ft. in order to accommodate vessels of a greater depth, that could readily be done at some increase of cost over what would have been incurred if made originally at the full depth of 40 ft.

Merits of Two Plans.—It has already been stated as the opinion of the Board that the time required for the construction of the Panama Canal with a summit level at 60 ft. above mean sea level will at best be only two years less than required for the construction of the sea-level canal. But as affecting this question of time, it should be observed that accidents during construction leading to an extension of the time required to complete the canal would be more likely to occur in the more numerous structures involved in the building of the lock canal than in the works for the sea-level canal. It has further been shown that the difference in cost between the two plans will not exceed about $71,000,000 in favor of the former, which must be reduced by the capitalized cost of the maintenance and operation of locks and by the cost of the overflowed lands, as before stated.

It is seen, therefore, that the lock design has inconsiderable advantage either in time of realization or ultimate cost over the one recommended by the Board for adoption by the United States Government, which possesses all the advantages of practically indefinite capacity for traffic, besides a degree of safety and uninterrupted operation which cannot be approached by any lock plan.

The Board desires to emphasize the fact that in its knowledge no great enterprise in connection with transportation, whether it be a canal, a railway, a harbor or docks, or similar work, has ever yet been completed of such size or proportions that subsequent enlargement did not become necessary. The Board is therefore of the opinion that in this particular case the United States Government should construct this great artificial waterway of such type and dimensions as to give it at the outset the maximum capacity that seems likely to be required, guaranteeing the greatest facility of operation, and leaving the canal as constructed with ample provision for a reasonable future increase of traffic and in condition for most speedy and economical enlargement in response to the future demands of commerce, without the undoing of any construction.

It is the belief of the Board that the essential and the indispensable features of a convenient and safe ship canal at the American Isthmus are now known; that such a canal can be constructed in twelve or thirteen years' time; that the cost will be less than $250,000,000; that it will endure for all time.

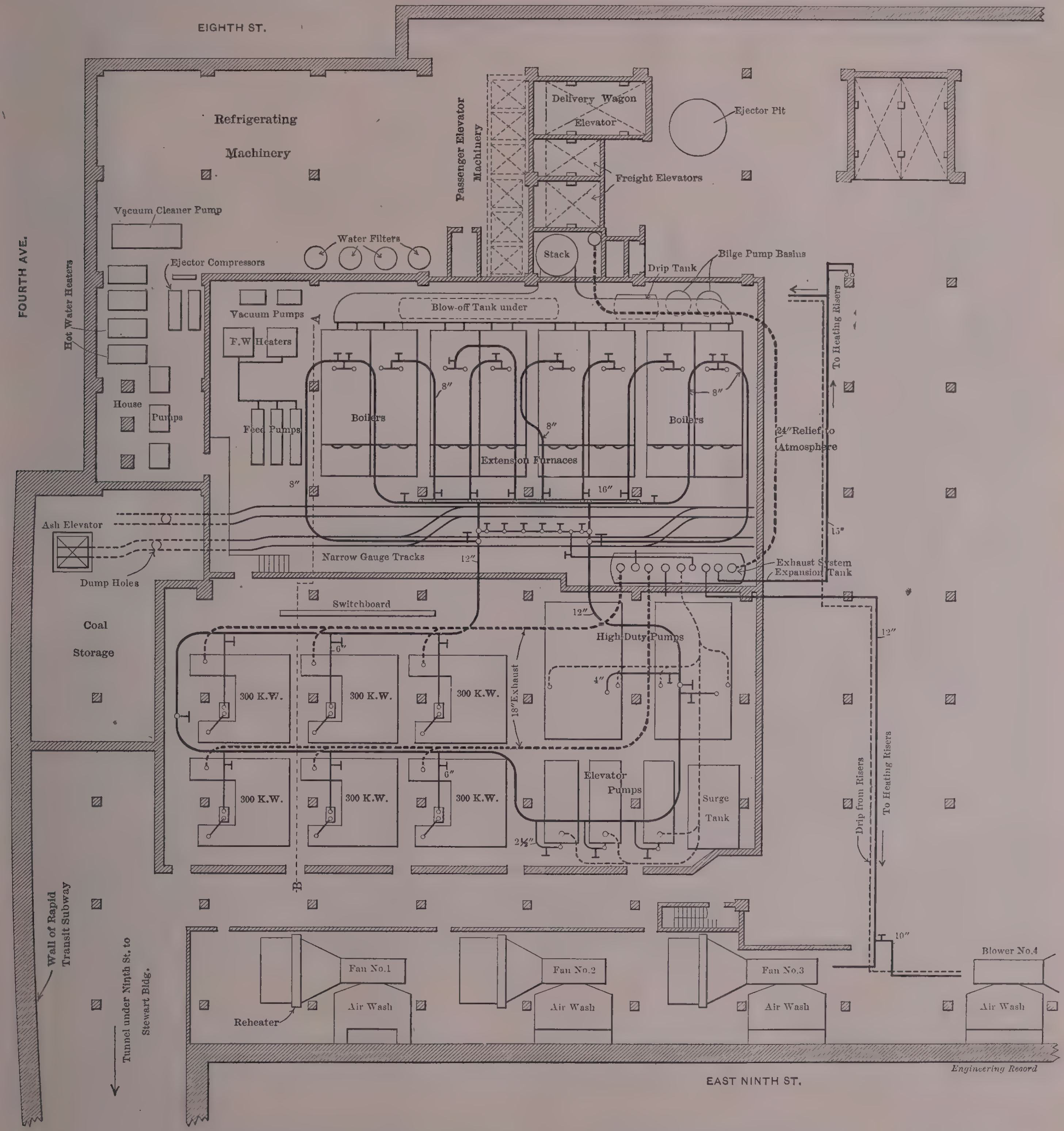
The recommendations of a minority of the members of the Board will be printed in a later issue.

Mechanical Plant of the New Wanamaker Store in New York.—I.

The new store of John Wanamaker will be one of the largest department stores in existence, supplementing the already large establishment in the old Stewart Building at Broadway, Fourth Ave., Ninth and Tenth Sts., which will be retained and several stories added. The installation resembles closely that of the new Wanamaker stores in Philadelphia, to which several references have been made in these columns. It differs, however, in that the power plant is to be located in the sub-basement of the new store building, whereas that in Philadelphia is located a block distant from the store. The plant in New York provides for the generation of electricity on an unusually large scale for lighting and power purposes and also the heating, ventilating and general mechanical service of both the new and old store buildings.

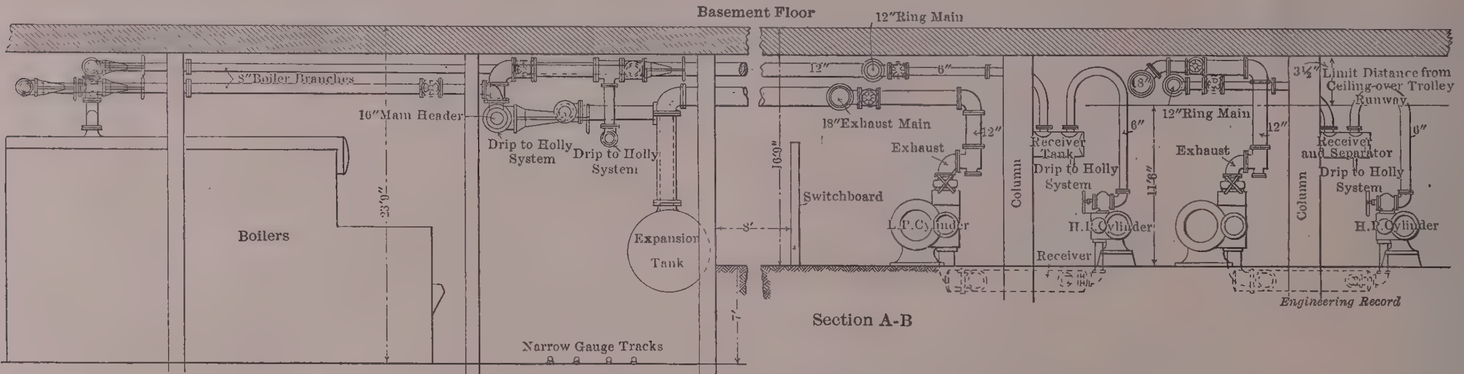
The new building is a fourteen story steel cage structure, on the block between Eighth and Ninth Sts. It occupies the entire 188x334-ft. block, with the exception of a space of 90x115 ft. at Broadway and Eighth St., on which is a building that could not be secured at present. The new building and mechanical equipment have, however, been designed to permit this section being added to complete the structure as soon as possession of the corner may be secured. The first eight stories and basement are devoted to retail purposes, and the upper six floors to storage, repair and packing purposes, with the exception of the ninth floor, which contains a large café together with its kitchen and the Wanamaker art gallery. The sub-basement provides the additional packing facilities and the shipping departments, at the Broadway end, and the equipment of mechanical apparatus at the Fourth Ave. end.

The Power Plant.—The equipment of the power plant for the New York store is similar to that in Philadelphia, which was described in The Engineering Record of Oct. 28, 1905, the principal differences lying in its location and arrangement. The plant occupies a space of about 144x200 ft. in the sub-basement. There are four sections of this space, one 56x109 ft. in size devoted to the boilers and their auxiliaries, another of 56x118 ft. devoted to the electrical generating apparatus and hydraulic elevator pumps, a third of



Plan of Mechanical Plant in Sub-Basement of New Wanamaker Store Building, New York.

24x192 ft. for the ventilating equipment, and a fourth, an irregularly shaped room at the Fourth Ave. and Eighth St. corner, occupying 4,000 sq. ft. of floor area, in which are located the house pumps, air compressors, refrigerating equipment, filters and other auxiliary apparatus. The boiler room, which is 38 ft. below the sidewalk level, has a 23¾ ft. clear headroom, whereas that of the engine room is 18 ft., and the other departments of the sub-basement 13¾ ft. This resulted in little clearance being available for a convenient arrangement of overhead piping in the engine room, a condition further aggravated by the installation of an overhead runway trolley system for the handling of machinery, which required a clearance throughout the rooms to within 3 ft. of the ceilings.



Section through Boiler and Engine Rooms Showing Arrangement of Steam Piping.

Boilers and Auxiliaries.—The steam generating equipment consists of eight Babcock & Wilcox water-tube boilers, each of 300-h.-p. rating. They are set in four batteries of two each, arranged in a single row on the Eighth St. side, with 30-in. passageways between them, an 8-ft. area at the rear for blow-off tank and piping, bilge pumps and other auxiliaries, and walkways above them for access to valves of the piping system. In front of the boilers there is a space of 18½ ft. for the firing floor, in which are laid the 20-in. cast-plate tracks for the coal and ash handling cars. Each boiler setting occupies a space of 9½x30 ft., or 570 sq. ft. per battery. Instead of the standard construction with flush-front furnaces, they are fitted with special extension furnaces, 7 ft. 4 in. wide by 8 ft. deep, which are equipped with hand-fired Coe shaking grates, designed for burning anthracite pea coal. This furnace arrangement, which is an adaptation of the reverberatory principle, has proved effective where the finer grades of anthracite coal are used for fuel.

The boilers are the standard inclined wrought-steel sectional water-tube type of the Babcock & Wilcox Co., all parts subjected to pressure being of forged steel designed for pressures up to 200 lbs. Each boiler has two steam drums, 36 in. in diameter, to which are connected twelve tube sections with sinuous forged steel headers, each containing twelve 4-in. tubes 18 ft. long, or 144 tubes in all. The total heating surface per boiler is 3,000 sq. ft. The brick settings, together with the extension furnaces, are covered throughout with vitrified asbestos, 2 in. thick, laid and jointed with asbestos cement. The steam drums and smoke flue are covered with asbestos air-cell sheets, 1½ in. thick, laid so as to give a 1½-in. air space.

Coal for the boiler equipment is stored in a 300-ton pocket beneath the Fourth Ave. sidewalk from which delivery is made directly to the narrow gauge cars. The coal bin occupies a space approximately 25x50 ft. east of the engine room, and extends up from the engine room floor to the sidewalk level, coal being dumped into the pocket directly through sidewalk coal holes from wagons in the street. A recess below the coal bunker in the boiler room permits the charging cars to be run directly beneath the bunker and coal chuted directly into the cars. The 20-in. gauge cast-plate track is set flush in the concrete floor of the boiler room, there being two lines of the track with cross-overs which permit cars to pass each other. There are two charging cars with hinged sides, each of one-ton capacity, and also a platform car which is used for handling ashes. As the latter are removed by the city carts, they are delivered to the sidewalk level in the regulation city ash cans, for which purpose there is a sidewalk elevator at the street side of the coal pocket, by means of which the platform car loaded with ash cans may be raised directly to the sidewalk level. This elevator is a plunger elevator operated by the elevator system in the building and is fitted with the narrow-gauge track so as to lift the platform car loaded with 6 to 8 ash cans, and thus reduce to a minimum the manual handling necessary. The cars and cast-plate tracks were supplied by the Hosher-Platt Co., New York.

The products of combustion are removed from the boilers by a steel-plate stack of 8 ft. internal diameter, rising 275 ft. at the rear of the boiler room through a large pipe shaft to the roof. A 5-ft. breeching leads from the various boilers with connections 3x4 ft. in area from each and delivers to the stack through a main connection 7x8 ft. in section. In both branch and main connections to the stack there are tight-fitting dampers, that in the main stack connection being controlled from the steam pressure by a Spencer damper regulator. Natural draft is depended upon for the operation of the furnaces.

Three boiler feed pumps are installed, which have duplicate delivery connections throughout, rendering a shut-down from trouble in the feed system practically impossible. The pumps are Laidlaw-Dunn-Gordon duplex outside-end-packed plunger type, each with 10x6x10-in. cylinders. Each has a capacity of pumping 35,000 lb. of hot water per hour. The feed water is preheated by either one of two Webster open heaters, installed in duplicate to permit of continuous service regardless of cleaning of trays and filters. Each is rated at 2,750-h.-p., and is capable of heating 116,500 lb. of water per hour from 45° to 210° F. To heat this amount of water 16,650 lb. of exhaust steam will be required per hour, which condenses and is added to the feed. An interesting feature of this equipment is that the heaters are located 110 ft. from the expansion tank, but they are treated like heating equipment, a Webster vacuum line attachment preventing them from becoming air bound. An attached oil separator on the 12-in. exhaust steam inlet removes oil from the exhaust steam.

Piping.—The high-pressure steam piping system includes a main and auxiliary header in the boiler room with a ring main encircling the engine and pump room, the arrangement of which tends to eliminate interruptions of service. The arrangement of connections to the headers, which is shown in an accompanying drawing, is a departure from the usual practice. All boiler delivery connections are carried directly to the main header, which is 16-in. piping divided into two sections, while the 8-in. auxiliary header is fed only through the connections which lead into the engine room to the ring main. The purpose of the auxiliary header is, in fact, more to supply the auxiliary equipment in the boiler room than to serve as a duplicate source of supply to the engine room; it does, however, form a connecting link which can be used in an emergency case to supply one-half of the ring main if the adjacent section of the main header is out of service.

It will be noticed in the drawing that each of the eight boilers has a direct connection to the main header through an 8-in. branch with a stop valve at the boiler nozzle and a gate valve at the header. This header is divided in the middle by a sectionalizing gate valve, and into each half section is connected one leg of the ring main, which is of 12-in. pipe. The auxiliary header is connected between these 12-in. leads to the ring main and from it are taken off branches to the boiler feed pumps, vacuum pumps, the heating system and other auxiliary supply. At this point there is an auxiliary boiler connection between the end boilers and the 12-in. connections to the ring main; each of these is an 8-in. boiler branch intended for a by-pass connection to the engine room if, by any chance, both sections of the main heater should become disabled. This arrangement safeguards the steam supply system without the necessity of running duplicate connections from each boiler to an auxiliary header, two boilers of this size being capable of carrying sufficient overload to prevent a shutdown of the plant in such an emergency.

The ring main supply connections enter the engine room at points 21 ft. apart and then separate, one side making a circuit of the Fourth Ave. end of the room where the generating units are located, and the other around the pump section of the room at the opposite end. This main is of 12-in. pipe throughout, the engine connections being of 6-in. pipe and those to the elevator pumps of 2½ and 4-in. pipe. Each of the engine connections has a steam receiver in place of the usual separator. This is a tank 4 ft. long by 20 in. in diameter, which serves as a combined condensation pocket and steam receiver in close proximity to the engine cylinder; condensation is removed from these receivers by connections to a high pressure drip system. The ring main is also sectionalized by two gate valves, one between the branch connections to each three engines and the other between the branches to each high-duty elevator pump. This divides the system so that the operation of units of every class is insured in spite of possible disablement of any particular section of this main.

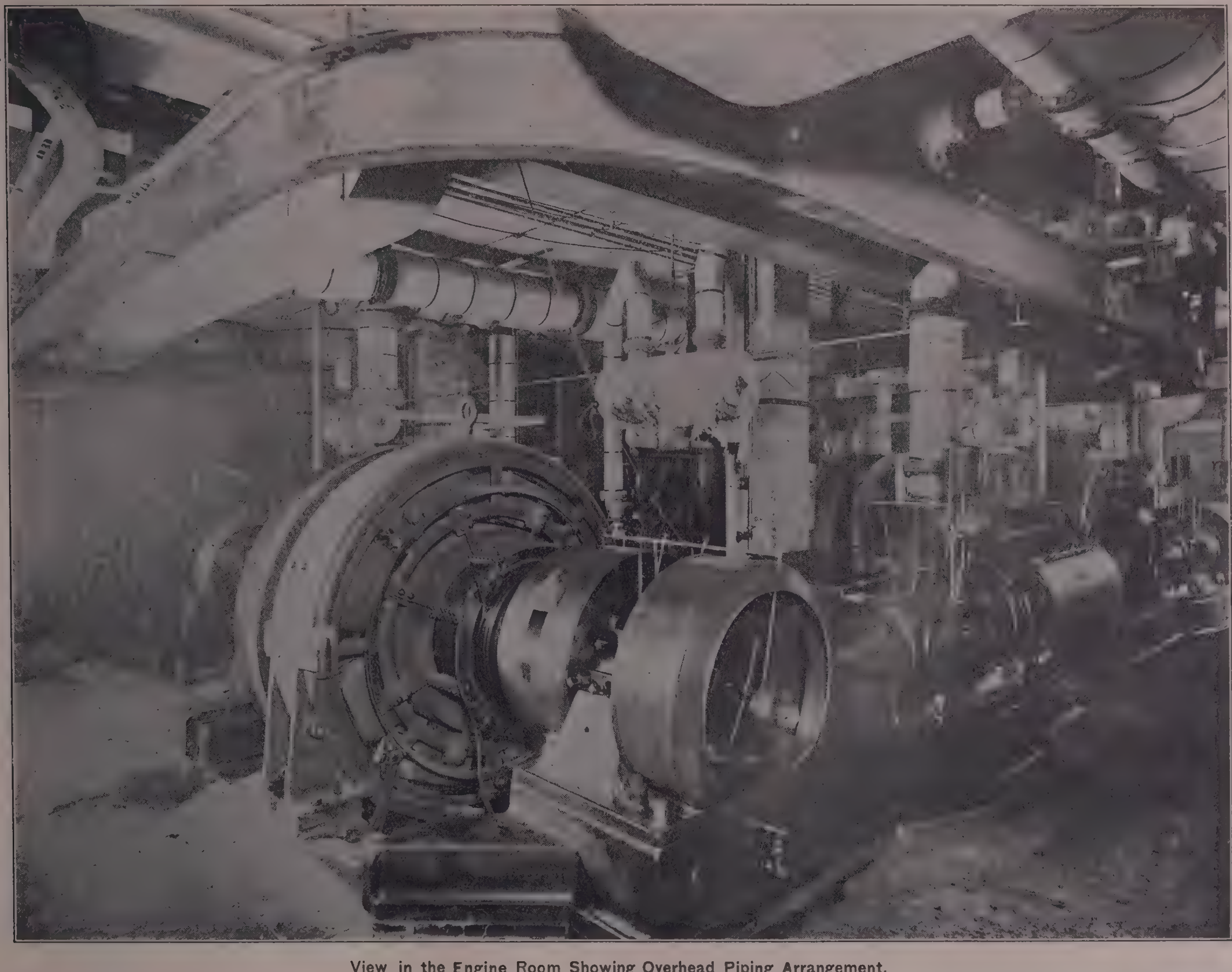
There are in addition to the above high-pressure connections, two 6-in. lines carried over to the old store in the Stewart Building across the street for the supply of steam to auxiliary steam-driven equipment located there. One of these is taken off the ring main in the engine room, while the other is connected to the main header in the boiler room. All piping is of extra heavy wrought iron with screwed flanged fittings on all lines above 3 in. in size. The pipe flanges as well as also all valves were supplied by the Crane Co., all high-pressure steam valves being of an improved bronze-mounted type with removable seats; all steam valves on 6-in. lines and larger are fitted with by-pass valves. The steam piping is protected with sectional asbestos air-cell covering 1⅛ in. thick, furnished by the Covering & Supply Co., New York.

The exhaust steam system is simplified by the use of an expansion tank, the function of which as receiver, muffler tank and oil separator, is similar to that in the power plant of the Philadelphia Wanamaker store, described in The Engineering Record of Oct. 28, 1905. This tank is a steel cylinder, 25 ft. long by 6 ft. in diameter, into which the exhaust steam from all steam using apparatus in the building is carried. This has not only simplified the arrangement of exhaust connections to the heating system, but also eliminated back pressure that might have been incurred in case a complicated exhaust system had been used. The exhausts from the generating units are carried to the expansion tank in two separate lines of 18-in. pipe, each of which takes care of three engines; the engine branch connections are each of 12-in. pipe and join these lines through Y-connections. The elevator pumps also deliver into an independent exhaust line, beginning in 8-in. pipe, with 6-in. branches to each of the three smaller pumps and enlarging to 12 in. at the connections from the high-duty pumps; here also the exhaust flow is facilitated by connections to this line through Y-fittings.

All connections to apparatus using the low-pressure steam are made from the expansion tank, that for exhaust steam to the feed water heater consisting of a 12-in. line taken off an independent valved connection to the tank, and carried across the boiler room with a 12-in. branch to either heater. A 4-in. branch from this line supplies low-pressure steam to a group of four Tobey hot-water heaters also located in the east end of the boiler room, for the hot water supply of the building. Relief in case of excessive back-pressure on the system is afforded by a Kieley back-pressure valve on the expansion tank and a 24-in. atmospheric exhaust riser which leads from one end of the expansion tank around to the rear of the boilers and up to an exhaust head on the roof. The connections to the heating system are also made at the expansion tank, consisting of a 10-in., a 12-in. and a 15-in. main which lead to the various heating risers throughout the building. There is also a 6-in. live steam connection to the tank from the auxiliary header in order to supply the heating system in case of deficiency of exhaust steam; this connection has a Kieley reducing valve, reducing from 150 lb. to atmospheric pressure. Other low-pressure connections from this tank are a 6-in. line to supply steam to the generator of the absorption refrigerating apparatus, and a 12-in. line to the Stewart Building for the heating system there. All this low-pressure piping is covered with ¾-in. asbestos air-cell covering, supplied by the Covering & Supply Co.

The boiler feed system is a simple arrangement of duplicate supply mains which extend from the pumps up and across the group of eight boilers with connections from either leg of the system to each boiler. The two mains are of 4 in. extra-heavy pipe with flanged fittings, one of brass and the other of wrought iron pipe, and are so connected to the pumps that any of the latter may deliver into either side of the system. Each boiler branch is 2½-in. pipe. They unite beyond the stop valves and thence lead to the boilers through a check valve and the control valve in series, the arrangement being such that check valves may be isolated for examination while the boilers are in service. Each pump has duplicate suction connections, one of 6-in. pipe from the feed-water heaters and the other a 4-in. line from the city water mains.

The boiler blow off system consists of a 6-in. header at the rear of the boilers, into which each boiler delivers through two 3-in. connections, each with a blow-off cock and gate valve in series. At the middle of this header a 6-in connection discharges into a blow-off tank immediately at the rear, the overflow from which is delivered to the sewers by bilge pumps, also at the rear of the boilers. The tank is a steel cylinder, 30 ft. long and 3 ft. in diameter, with an 8-in. vapor connection leading to a 9-in. vapor outlet rising in the pipe shaft alongside of the smoke-stack to the roof.



View in the Engine Room Showing Overhead Piping Arrangement.

The bilge pumps are Yoemans vertical centrifugal pumps and are installed in duplicate in the bottom of a bilge tank set 6 ft. below the boiler-room floor level so as to be 1½ ft. below the lowest drain connection and thus serve to collect all drainage from the boiler room. Each pump has a capacity of 100 gal. per minute raised to the street sewer level, about 30 ft. above, and is driven by a vertical Crocker-Wheeler motor mounted on the pump shaft extended above the tank, the motor being controlled automatically by a float operating a Cutler-Hammer motor starter. The motors operate from the 230-volt power mains of the building.

There are two drip systems, one for the clean drips from the high-pressure steam mains and another for the dirty drips containing oil or other foreign matter from exhaust steam. The clean high-pressure drips are cared for by a main corresponding in arrangement to that of the header and ring main of the high-pressure system into which connections are made at all pockets, receivers and other points where condensation may accumulate. Condensation is removed from this line by the Holley system by which delivery is made directly to the boilers; for this system there is installed the usual receiving header or tank beneath the lowest drip-connection level and the usual elevated tank from which the gravity connection leads to the boilers through the feed connections. The other system consists of a similar line with drip connections to all points where condensation might accumulate in the exhaust steam supply mains. This system delivers to a 4x6-ft. cylindrical receiving tank at the rear of the boilers, from which the discharge is directly to the bilge tanks. Vapor accumulating in this tank is removed by a 4-in. vent joining the vapor pipe from the blow-off tank leading to the roof outlet. All drip lines of both systems are carried in the engine-room floor in trenches with removable cast-iron cover-plates, of which a complete system has been installed around all the pumps and machines.

Engine Room Equipment.—The engine room contains the electrical generating machinery for the building, the control switchboard, and the pumps for the 29 hydraulic elevators. There are six direct-connected steam driven generating units, each of 300-kw. capacity. The machines are designed for medium speed operation and run non-condensing, the exhaust steam being utilized in the heating system, open feed-water heaters and the generators of the absorption refrigerating machinery. The engines are horizontal cross-compound Buckeye type, each with 16½ and 30½-in. cylinders and 27-in. stroke. They operate at 150 r.p.m. and are capable of developing 650 h.-p. with a steam pressure of 150 lb. They are fitted with a gravity oiling system, a force-feed cylinder lubricator, a combined telescopic crosshead oiler and indicator reducing motion, but the cylinder tail rods, usual in this type of engine, were omitted owing to lack of floor space. The engines were built by the Buckeye Engine Co., Salem, O. The electrical generating machinery and also the elevator pump equipment will be described in later articles.

On account of the numerous columns in the basement it was necessary to locate the engines so that one of these columns should come between the high and low pressure cylinder of each engine and in such a manner that the receiver could not be placed in a direct line between the high and low pressure connections. The receiver was therefore located in each case about mid-way between the column and the base for the generator, and was kept as close to the floor as possible on account of the fact that the basement is below mean high water mark. For this reason, also, it was necessary to keep all pipes above the floor as much as possible and the low-pressure cylinders were therefore turned bottom side up, which allows the steam to enter the under side of the chest and the exhaust to escape from the upper side of the chest, which is the opposite of the usual arrangement. It has been found that with the low-pressure cylinder and chest well drained no trouble is experienced on account of this peculiar arrangement. The receivers, connections and drip piping are located in trenches covered with checkered cast-iron plates.

The Sewage Ejectors.—The sewage and all drainage from the basement and sub-basement levels are removed to the sewers above, independently of the bilge pump equipment used in connection with the boiler blow-off system, by means of Shone equipment. The lowest section of the sub-basement is nearly 38 ft. below the street level and thus about 30 ft. below the sewers in the adjacent streets, and as much ground water was encountered the pneumatic system was adopted for its continous automatic removal. For this purpose the building has been divided into two entirely independent sanitary districts, one at either end, each having a sewage collecting sump. Two Shone ejectors are located at each sump, each rated at 100 gals. per minute. A feature of this system is that it is entirely enclosed, preventing escape of odors, and that it will automatically handle large quantities of sewage rapidly, thus providing against accidental flooding of the basement in any case. Flap check valves on either side of the ejector prevent back-flow from the sewers.

The compressed air supply for this system is furnished by a duplicate equipment of motor-driven air compressors which automatically maintain a pressure of 14 lb. in a large storage tank. Each compressor is an American horizontal crank and flywheel compressor with a single double-acting 10x10-in. cylinder. They are water jacketed with automatic control of the water supply, and each has a capacity for operating all four ejectors to their total combined capacity of 400 gals. per minute. Each compressor is driven through a Morse chain drive by a 10-h.-p. Crocker-Wheeler motor which runs at 825 r.p.m. on the 230-volt local power system of the building. These pumps are both controlled automatically from the air pressure by means of an equipment of Bourdon-type gauges with limit contacts, which control the motors through relays and solenoid motor starter systems. These control equipments are mounted upon a neat white marble switchboard near the compressors together with an air pressure gauge. This equipment was installed by the Shone Co., Chicago, Ill.

The mechanical plant of the Wanamaker Building was, like that of the new Wanamaker store at Philadelphia, designed and its construction supervised by D. H. Burnham & Co., architects, Chicago, the design of the mechanical equipment having been in charge of the late C. M. Wilkes of that company. The boiler room equipment and auxiliaries and the steam piping system were installed by Gillis & Geoghegan, New York, who have also installed the heating and ventilating equipment. The engines and electrical equipment were installed by the Thompson-Starrett Co., New York.

(To be Continued.)

Electricity is personal property, according to a decision of the California Court of Appeal in Terrace Water Co. v. San Antonio Light & Power Co., 82 Pac. Rep. 562. Under the civil code of the State, declaring that what may be owned is property and that every kind of property which is not real is personal, the court decided that a plaintiff was entitled to recover for breach of contract for delivery of electricity under a complaint charging a breach of contract to sell and deliver personal property.

General Features and Foundation Details, New Office Building, New York Central Lines.

Among the improvements now under way for the New York City terminal of the New York Central & Hudson River Railroad, one of the most interesting and important is the 275x462-ft. twenty-story steel-cage building to contain the offices of the company and of tenants and a sub-station of the United States Post Office. The building will occupy two entire blocks bounded by Lexington Ave., 43d St., Depew Place and 45th St., and will be connected by a skylight roof over Depew Place with the new passenger station of the terminal.

It will be rectangular in plan and will cover the whole area of the site up to the first office floor, two stories above the street level, above which there will be three interior 62x130-ft. light wells. The twenty full stories will include an attic or pipe gallery at the top of the building, 16 office floors, one pipe gallery floor between the third and fourth office floors, one post-office floor in the second story above the street on the Lexington Ave. side, one story at street level, and one complete story below street level, which will be occupied as indicated in the principal sectional elevations by the tracks of the local and express trains running into the adjacent station, besides which there will be a second story beneath ground level under a portion of the Depew Place side of the building, which will be used for the platforms and tracks for suburban trains. This will really provide a total of 21 stories eventually, but the present scheme contemplates building the structure only eight stories above the street. The northern half will be built immediately and its basement, through which trains will eventually pass on the way to and from the new terminal station, will be used as a temporary terminal while a portion of the yard reconstruction and station building is in progress. After this temporary terminal is transferred to the west side of the yard and the sub-post-office is permanently installed in the second story of the building, the south half will be erected.

The steel work and other portions of the structure are, however, designed for the future extension to the 21st story as above described, and the architectural motive treats this first-constructed portion of the building as a massive base, above which the Lexington Ave. front will be relieved by a facade of enormous engaged stone columns seated in a return of the front wall and rising from the post office to the pipe gallery floor. At the fourth office floor the exterior walls are offset about 3 ft. inwards so as to accentuate the separation of the lower portion of the building as a base from the upper portion as a shaft. At the fifteenth office floor there is an ornamental projecting course and at the roof line there is a very wide and heavy projecting steel cornice.

These features, together with the requirements for the spacing of columns so as to permit the desired location of tracks in the basement, involved some unusual and difficult features of construction which have been met with novel and interesting methods and detail of design. The building will be absolutely fire-proof and will be of steel-cage construction, although the outer walls are self-supporting from the street level to the first cornice at the fourth office floor, where there are girders to carry the main stone cornice, above which the walls will be carried at every story by separate girders supported by the exterior columns. The walls are of cut stone and all of the steel work is thoroughly protected.

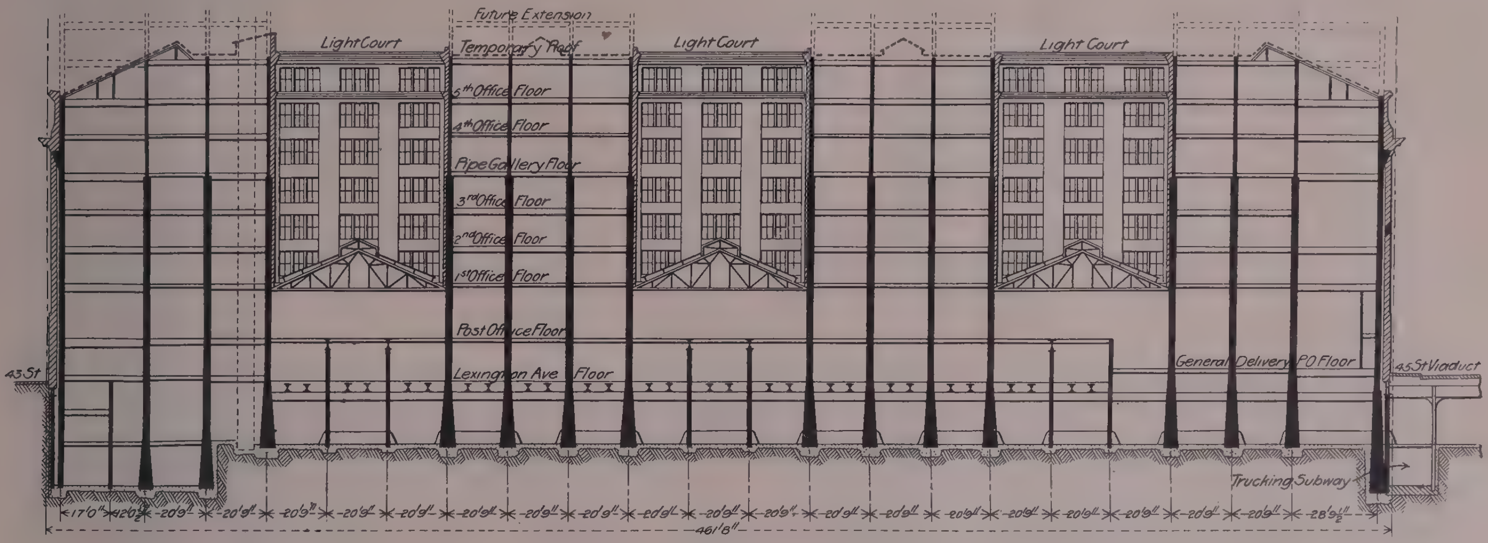
The floors are of reinforced concrete construction and are all proportioned for loads of 160 lb. per square ft. except the Lexington Ave. street floor and the post-office floor which are proportioned for 365 lb. each. In accordance with the New York building laws the columns are assumed to carry decreased percentages of the maximum loads of the successive floors counting from the top down. For the roof they carry 125 lb. per square ft., for the upper floor 160 lb., for the succeeding lower floors they carry respectively 156¼-lb., 152½-lb., 148¾-lb., 145-lb., 141¼-lb., 137½-lb., 133¾-lb., 130-lb., 126¼-lb., and 122½-lb. per sq. ft. for the seventh and remaining office floors, except at the post office and street floors where 182½-lb. is allowed.

The height of the first story above the street on the Lexington Ave. side is 17 ft. 2 in., of the post-office story is 18 ft. 10 in. The heights of all the succeeding stories, except the third office story and the pipe gallery story which are 12 ft. 8 in. and 12 ft. 10 in., are 12 ft. 6 in. up to the 14th office story which is 17 ft. The 15th and 16th office stories are 13 ft. 6 in., and the upper pipe gallery story is about 14 ft. high in the clear to the hanging ceiling. Above this ceiling the pitch of the flat roof brings the highest point up to about 275 ft. above the level of the street at Lexington Ave. The total weight of structural steel in the final 20-story building will be about 35,000 tons, and in the 275x462 ft. first part of the building as finished to the temporary roof just above the level of the sixth office floor, it will be about 17,000 tons.

The arrangement of the railroad tracks passing through the basement of the building required that the columns should be located in longitudinal rows with spaces between most of them sufficient for the clearance of three lines of track. This made it necessary to locate the columns 44 ft. apart on centers, thus providing a span which was not economical for the construction of the office floors. It was desirable to avoid as much as possible the obstruction of the street and post-office stories by columns so the floors there are carried on deep plate girders, although they do not secure economy of steel weight.

The girders in the first office floor are made about 50 in. deep as it is permissible for them to project below the ceiling in the post-office story. They are thus strong enough to carry the intermediate columns for the next two upper stories, but are not competent to carry intermediate columns for the total number of 18 stories which will eventually be built above this level. Very heavy riveted longitudinal trusses will, therefore, connect the interior columns just below the fourth office floor. These trusses are made one full story in depth and occupy the space enclosed by the large main cornice at the top of the base portion of the building. They are designed to carry the roof and 15 stories above their bottom chords. As it was impossible to provide space below street level for the distribution of pipes, mains and conduits, and as it was imperative to have considerable space for such purposes, it was determined to arrange an upper story for them. Architectural features were, therefore, made to conform with these conditions and the pipe gallery was located in the zone of the deep main cornice where the lack of lighting through the outer walls was not objectionable. This use of the space and the structural cost which might not under ordinary conditions be advisable, were here justified and were advantageously used for the architectural features.

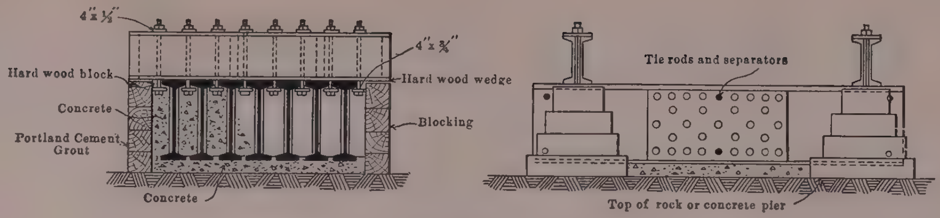
The columns which carry the pipe gallery trusses are subjected to enormous loads and in order to provide for a satisfactory distribution of pressure on the grillage beams it was finally decided to build them of special construction with the lower portions tapered as shown in the longitudinal section. This construction affords a simple solution for a difficult problem and is considered satisfactory both by the designer and by the steel companies who were in conference on the preliminary designs.



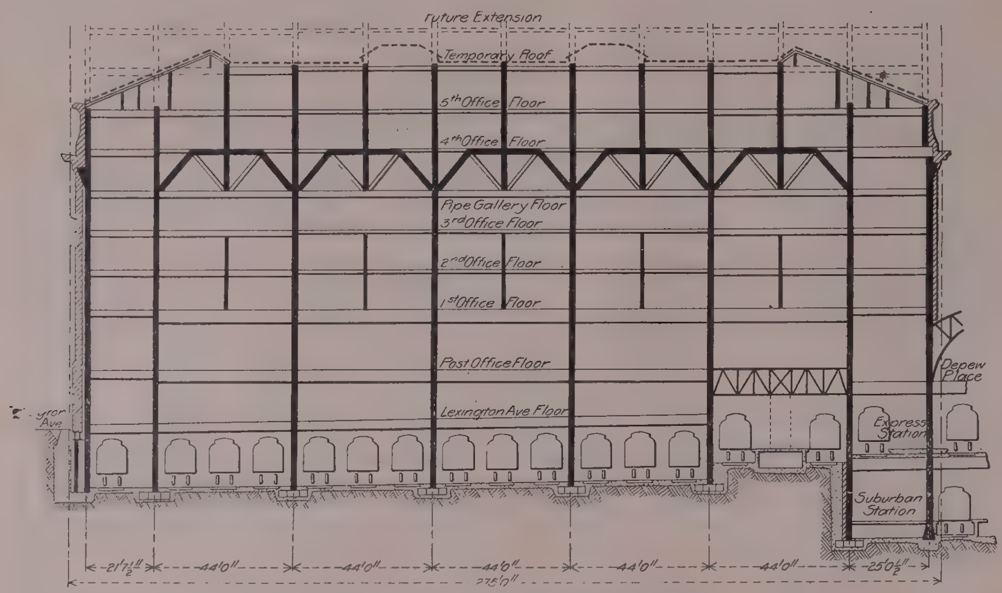
Longitudinal Section of Lower Part of Building.

General View of Office Building of the New York Central & Hudson River Railroad.

The framework of the half building has 90 main columns, all but two of which are located at the intersections of eleven transverse lines, with nine 20-ft. 9-in. spaces and one 28-ft. 9½-in. spaced between them, and eight longitudinal lines, the five interior ones being 44 ft. apart and the two outsides ones 25 ft. ½ in. and 21 ft. 7½ in. apart. Above the fourth office floor the longitudinal rows of interior columns are only 22 ft. apart on account of the interposition of the intermediate columns carried, as already described by the heavy trusses.



Method of Setting Grillages.



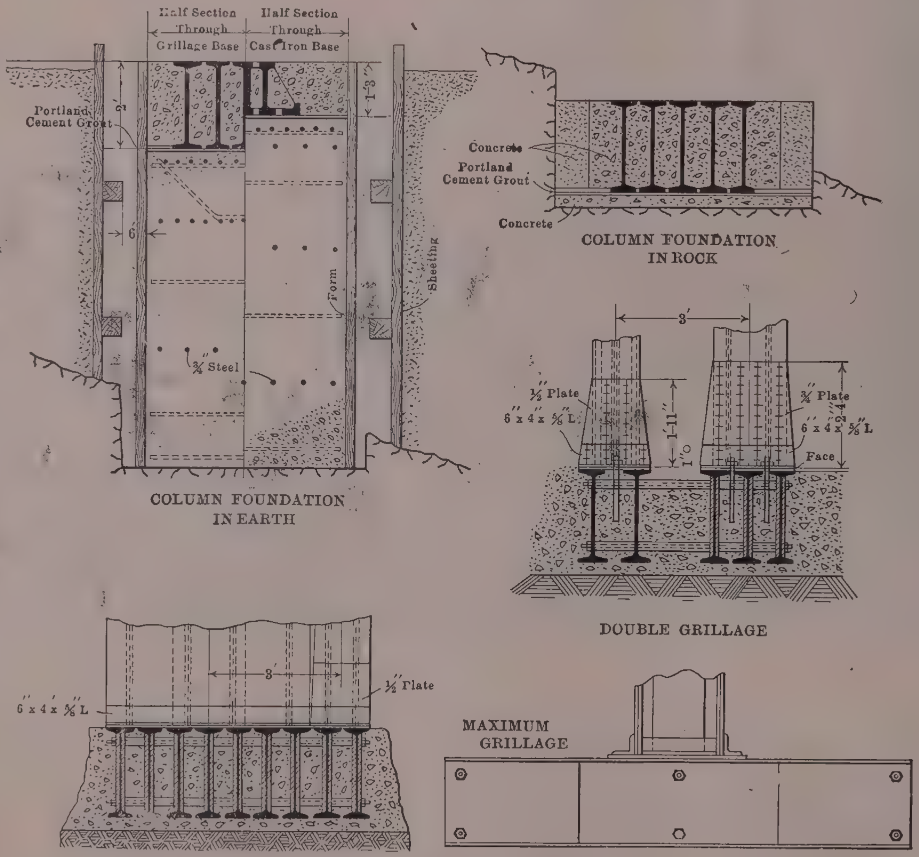
Transverse Section of Lower Part of Building.

The foundations for all columns are carried to solid rock, and the footings are made with I-beam grillages where it was found at the required level. Where the excavation had to be carried deeper to secure bearing on sound rock the columns have cast iron pedestals or I-beam grillages seated on reinforced concrete piers. The grillages are proportioned so as to reduce the maximum pressures on their lower flanges to 500 lb. per sq. in., equal to 36 tons per sq. ft., an amount which is believed to be conservative in view of the pressure of 50 tons per sq. ft. allowed on good rock by the building department of New York City.

The few concrete piers have vertical sides and are built in moulds in sheeted pits. Except for a thin layer of grout under the lower flanges of the pedestals and grillage beams they are monolithic masses of concrete extending up to subgrade and entirely enclosing the webs and top flanges of the grillage beams and pedestals and filling all interstices between webs. They are reinforced by horizontal round bars in crossed layers about 18 in. apart. The bars parallel to the grillage beams are ¾ in. in diameter and 4 in. apart, those in the alternate layers at right angles to them are 3 in. apart, each bar being bent 180 deg. to a 1½-in. radius at each end, the ends returning parallel to the bar to its center point where they nearly meet. This construction permits the same unit pressure on the pedestals or grillage flanges as is used where there is no concrete, thus providing for the requirements of the building department which would allow only 12 tons per sq. ft. pressure on concrete piers without reinforcement. Where the concrete piers are used their footings must be at least 10 in. below the surface of the rock and the latter must be dressed with heavy hammers. Concrete under the lower flange of all grillage beams must have a minimum thickness of 4 in.

All of the grillages are made with 100-lb. 24-in. steel I-beams connected with three pairs of ¾-in. tie rods having gas pipe separators. The beams vary from 7 to 10½ ft. in length and most of them have their webs reinforced by plates from 3 to 4 ft. long riveted to both sides in the center of the beam. The majority of these plates are ¾ in. or 1 in. thick, a few of them being ⅞ in. The edges of the plates are accurately planed to fit the fillets of the beams, thus enabling the plates to serve not only for the reduction of the shear in the web, but also to take a portion of the bending moment and reduce the stresses in the flanges. The beams are arranged in groups of from three to nine for each column. The majority of the columns carrying the heavy trusses have seven beams in each footing. The intermediate columns in the 45th St. wall have nine beams in each footing.

On the 45th St. and Lexington Ave. fronts of the building there are short one and two-story columns which carry only the main wall from the street level to the main cornice. These columns are located on the center lines of the main wall columns which carry the floors and are 3 ft. outside of them. They are seated on pairs of beams which with the beams under the main wall columns really form single grillages united by the same tie bolts and separators. The columns supported by these grillages all have ordinary bases which are extended to engage the full width of the beam flanges and distribute the loads fully over them. The bases of the columns are faced for bearing on the beams and are connected to them as indicated in the cross section by rag bolts between the beam flanges. Other grillages which have three or four beams each receive directly the extended bases of the columns in a similar manner. The wide grillages and those of five or more I-beams most of them receive the feet of special columns built with their lower sections tapered to a width equal to that of the grillage. In six cases under courts where the columns were much shorter and have lighter loads they are seated on cast iron pedestals made with 1¼-in. vertical longitudinal and transverse webs and top and bottom flanges, the outer edge of the lower flange being stiffened by a short vertical web, and holes being left through the



Arrangement of Foundation and Grillages.

top flange to provide for filling the interior solid with grout and concrete. These pedestals are calculated for maximum loads, 484,000 lb., and are 15 in. high with 29x35-in. bases.

The top flanges of the grillage beams will be set at elevations from about 20 to 50 ft. below street level and unusual care will be taken to secure great accuracy in height and level. It is specified that the rock footings shall be covered with concrete leveled to clear the lower flanges of the beams. Timber blocking is then to be built on each side of and parallel with the grillage. On it there are to be placed and accurately leveled with hard wood wedges, two pairs of transverse 15 in. channels riveted together 1¼ in. apart back to back and having their top and bottom flanges planed. Narrow transverse ½-in. bearing plates across their top flanges will receive vertical 1-in. bolts nearly 2 ft. long. These bolts will be spaced between the grillage beam top flanges and will support them by bearing clips, as indicated in the detail.

The grillage beams will be suspended by these bolts, which will draw their top flanges tightly against the bottom flanges of the tranverse channels. They will be maintained accurately in their required locations by longitudinal and transverse braces. The grillage beams will be grouted with Portland cement to about 1 in. above the bottom flanges. Moist concrete will then be rammed between the beams by narrow tamping bars until all water disappears, after which the spaces will be filled with concrete to the level of the top flanges and after it has set the channels and blocking will be removed. These buildings are part of the work due to the change in motive power from steam to electricity in charge of Mr. W. J. Wilgus, vice-president of the company.

The design of the building was commenced in July, 1905, and the first contract for its construction was awarded in January, 1906. Reed & Stem and Warren & Wetmore are the associated architects. Mr. Charles A. Reed is the executive architect, Mr. H. G. Balcom is in charge of the steel work and structural designs, and Messrs. Leem & Schultze, of the architectural design. The John Pierce Co. is the general contractor. The contract for the substructure was awarded to the O'Rourke Engineering Construction Co. The contract for the structural steel work has been awarded to the McClintic-Marshall Co.

Hydro-Electric Elevator in Tudor Apartments, Chicago.

The accompanying views illustrate the electrically driven hydraulic machinery for operating the passenger elevator of the Tudor building, a five-story apartment house situated at the corner of 43d St. and Ellis Ave., Chicago. The plant constitutes a most interesting application of the induction motor to the operation of hydraulic passenger elevators.

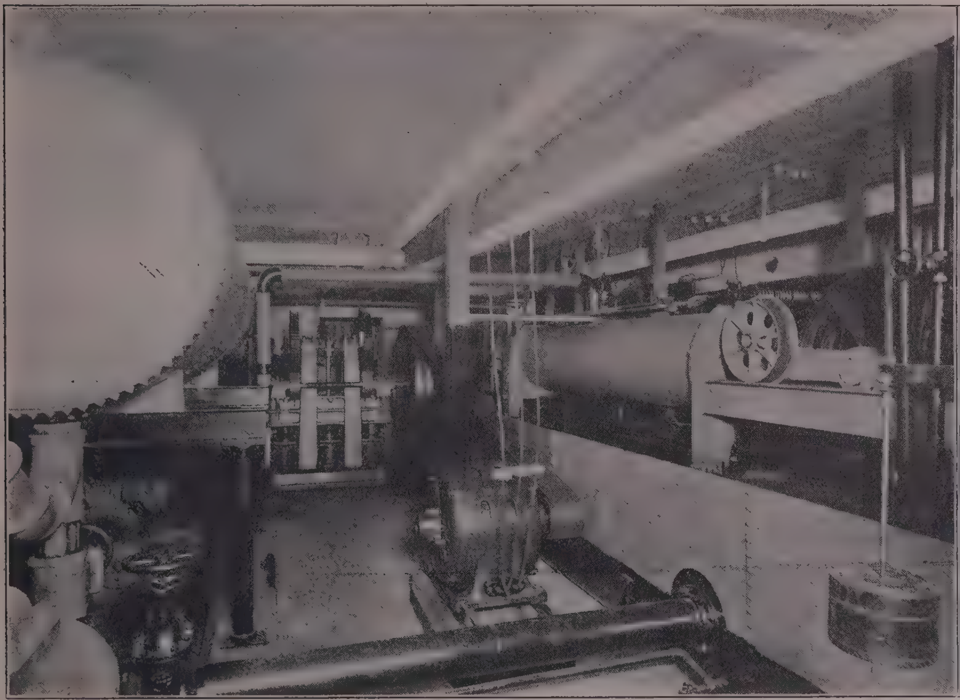
The motor is a 15-h.-p. 220-volt General Electric Co.'s Form K induction motor, taking current from the mains of the Commonwealth Electric Co., and is provided with a special high-resistance rotor in order that the starting current may not attain a high enough value to interfere with the voltage regulation of the supply circuit. The motor is belted to an 8x10-in. vertical single-acting triplex pump, which discharges into a compression tank against an average pressure of 80 lb. per square inch, thereby providing the necessary hydraulic power for operating the elevator.

At the right hand of the larger view may be seen the weight lever and weight of a Mason regulator which starts and stops the motor through the instrumentality of a form I oil switch, the small picture clearly shows this controlling apparatus. It will be seen that the operating lever of the regulator is connected to the lever of the oil switch. The spring attachment, with which the oil switch is ordinarily equipped in order to give a quick break, was removed, as the motion of the Mason regulator is positive and gives a speed of about 8 in. per second the operating lever.

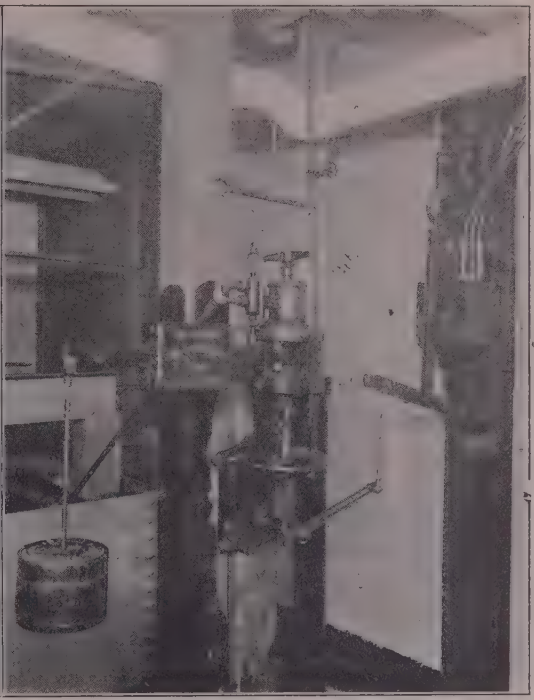
When this controlling apparatus was first installed, the regulator was set to start the motor when the pressure fell to 70 lb., and to stop the motor when the pressure rose to 85 lb. Later it was found that a pressure of 35 lb. was sufficient to operate the elevator with average load. The adjustment of the regulator was accordingly changed so as to start and stop the motor less frequently, thus giving longer periods of work and rest. With the motor shut down after having brought the pressure to the maximum, the elevator makes three average trips before the pressure falls to the point at which the regulator operates to start the motor. It takes about three minutes after the motor is started to bring the pressure back to the maximum, and the motor delivers 13½ h.-p. when operating against the maximum pressure.

Notable features of this installation are its simplicity, and the fact that it utilizes standard apparatus; the only special features being the omission of the quick-break spring from the oil switch, and the substitution of a high resistance rotor in the otherwise standard induction motor.

The installation was put into service about the first of June of last year and has been operated continuously ever since, with very little attention, and with no expense except for current, which is costing the owner $40 per month at 10 cents per kilowatt-hour. The previous cost of operating with steam was $95 per month for fuel and $35 per month for night engineer; a total of $130 per month.



General View of Elevator Plant in Tudor Apartments, Chicago.



Regulating Apparatus Details.

The Pollution of Water.

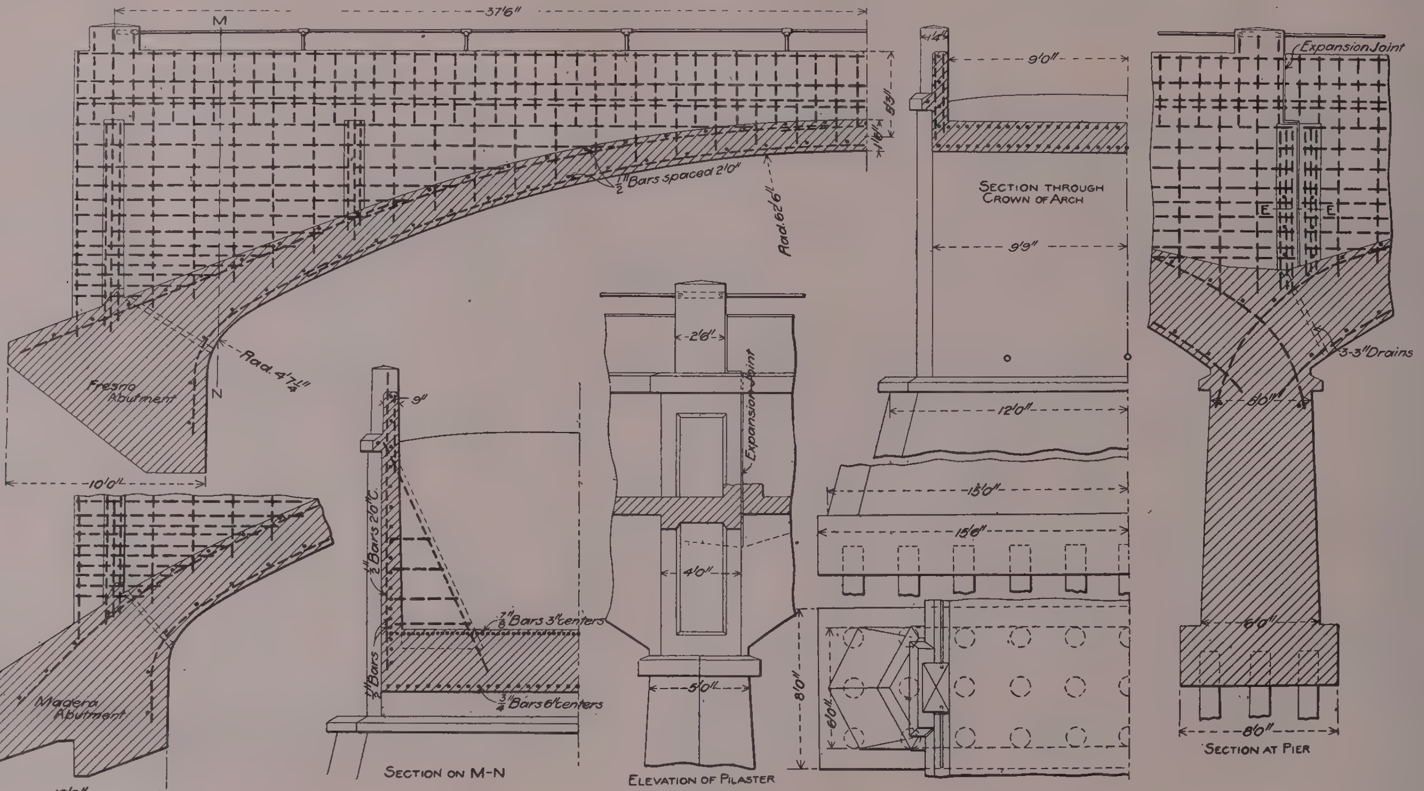
The pollution of water by manufacturing wastes was recently considered by the Indiana Supreme Court in West Muncie Strawboard Co. v. Slack, 72 N. E. Rep. 879. The court decided that one who creates a public nuisance is responsible to individuals specially damaged, not only for the actual loss he alone has caused them, but also for the damages caused by similar acts of third persons which independently concur in causing the injury complained of. Under the State laws providing that whoever unlawfully diverts any stream of water from its natural course or state, to the injury of others, shall be fined, etc., persons who maintain paper factories on the banks of a creek and discharge chemicals into it, destroying the fish in it, polluting it and the connecting streams and rendering their water unfit for stock, are guilty of maintaining a public nuisance. The fact that a water course is already contaminated does not entitle other persons to aid in its contamination, or preclude persons injured thereby from recovering of them damages for the injury.

IN AIR PUMPS having cylinders over 10 in. in diameter, Mr. C. B. Albree has found it advantageous to substitute ordinary hemp packing in place of the usual iron packing rings for the pistons.

The Pollasky Reinforced Concrete Bridge.

There has recently been completed at Pollasky, Cal., one of the largest reinforced concrete bridges in the country. There are ten 75-ft. arched spans and at each end the concrete of the abutments is carried back as wing walls for 15 ft., making the total length of the structure 780 ft. The width inside the spandrel walls is 18 ft. The structure affords communication across the San Joaquin River between Madera and Fresno counties. Before its completion, heavy teams had to ford the river, as the old bridge in the vicinity is not strong enough for any but the lightest traffic. There is considerable heavy teaming done already, and the lack of a suitable bridge was considered one of the factors which acted most strongly in retarding the development of the region.

The ten arches, the piers and the abutments form one monolithic mass, but the spandrel walls have expansion joints over each pier. The footings of the piers are 31 ft. long, 8 ft. wide and 3 ft. thick and each rests on 33 redwood piles driven through the sand and gravel to bedrock. The piers proper are 6 ft. wide and 30 ft. long at the base and 5 ft. wide and 24 ft. long at the top.



Diagrams Showing General Design of Arch and Location of the Masonry.

The entrados of the arch ring has a radius of 62½ ft. and is 18 in. thick at the crown, and 26 in. thick at a point 12 ft. from the center of each abutment and pier, where the thickness begins to increase rapidly. The longitudinal reinforcement at the piers consists of ⅞-in. bars spaced 3 in. apart in the upper part and ¾-in. bars 6 in. apart in the lower part. Both courses are crossed every 2 ft. by transverse ½-in. bars, and are 2½ in. from their respective surfaces. The bars are wired together at their intersections. The reinforcement in the lower part of the arch remains the same for the whole span. In the upper part, however, the 75 longitudinal bars run only 12 ft., and then their number is reduced one-half, making the spacing 6 in. This continues for 9 ft. more where the size of both longitudinal and cross bars is reduced to ¾ in., and the spacing is increased to 12 in. It should be noted in the illustration of the section of the arch at the crown that the upper longitudinal reinforcement is incorrectly shown as 39 instead of 19 longitudinal bars.

The spandrel walls are 9 in. thick at the top and are slightly battered so as to be 1 ft. thick at the bottom over the piers. Every 2 ft. there is a ½-in. vertical rod running from the top down into the arch concrete. These rods are crossed by ½-in. transverse bars from 18 in. apart at the top to 6 in. at the bottom. The inner face is reinforced with ½-in. vertical rods on 12-in. centers; these extend down only about 3 ft. Both sets of rods are 2 in. from their respective faces. Over each pier is a buttress 16 in. thick and 30 in. wide, and on one side of it is the expansion joint, formed by placing a layer of tarred paper in the molds. Near the haunches of the arch are two pairs of buttresses 12 in. thick with three ¾-in. reinforcement rods in their lower portion and two in the upper part; these rods run into the concrete of arch and spandrel wall so that the buttress forms a kind of knee brace. The spandrel walls are provided with a railing of light pipe.

Six sets of falsework were used for the bridge, being moved from span to span until the work was completed. Each center was carried on five bents of 8x12-in. posts, having 6x12-in. caps. Just below the caps each longitudinal line of posts was connected by a pair of 2x8-in. planks. The five frames of the center were supported on the caps by wedges. The ribs of the center, on which the 2½x8-in. lagging was placed, were pairs of 2x12-in. plank with 4x10-in. fillers between them, the whole nailed together with 7-in. spikes. The struts consisted of a pair of 2x6-in. plank with a 4x6-in. piece between them, the latter projecting up into the space between the outside plank of the rib. At the bottom each strut is simply butted on a 6x8-in. stringer, but on either side of the latter was a 1½x12-in. plank through which and the feet of the struts ½-in. bolts were passed. In laying out the centers provision was made for a 1-in. camber by using a radius of 61 ft. 11 in. instead of 62 ft. 3¾ in. This gave a rise of 10 ft. 11¾ in. in place of 10 ft. 10¾ in. as figured without allowance for camber.

The concrete for the arch and lagging was put in simultaneously, the illustrations showing the molds clearly. The siding plank was all 1-in. stuff, held by 2x6-in. verticals 26 in. apart. These were tied together by 2x6-in. plank. Some of the special details of the molds are shown on an enlarged scale in an accompanying illustration. In the cross-section of the molds is shown the framing for carrying the two 18-in. tracks used in handling materials.

The concrete in the foundations and piers up to the line of reinforcement was mixed 1:3:6 and above that 1:2:4½. The reinforcement was exclusively of Johnson corrugated bars of steel having an elastic limit of 50,000 lb. The cement used was the Sunset brand, made by the Pacific Portland Cement Co. The aggregate was sand and gravel from the river bed.

The materials were stored near the Fresno pier where the concrete mixer was located, and delivered by the two service tracks already mentioned. The track had a slight uniform down grade from the mixer to the other end of the bridge. The spandrel filling for the completed bridge was river gravel raised by a bucket elevator near the center of the structure into hoppers, from which it was discharged into the cars on the service tracks.

The bridge was designed by Mr. John B. Leonard, consulting engineer, San Francisco, from surveys furnished by Mr. Scott McKay, county engineer of Fresno county. The strain sheet shows a normal thrust of 42,000 lb. at the piers and 31,200 lb. at the crown, and a shear of 21,300 lb. at the piers.

The contract was taken by the Pacific Construction Co. of San Francisco, Mr. C. F. McCarthy, president, and Mr. F. A. Koetitz, vice-president and chief engineer; the details of the centering were designed by the latter. The concrete work was sublet to the Worswick Street Paving Co. of Fresno, which has recently been engaged on considerable similar construction.

Notes on Large Steam and Electric Locomotives.

The Baltimore & Ohio R. R. is the only American road which has been operating large steam and electric locomotives, and for this reason a paper on the subject presented last week before the New York Railroad Club by Mr. J. E. Muhlfeld, general superintendent of motive power, is of decided interest. It should be prefaced with the remark, however, that in the discussion following its presentation it was pointed out by some of the electrical engineers present that the two electric locomotives used by the author in his comparative data were of an old type working in a service that no steam locomotive could handle. Consequently figures depending on their operating results should not be used in comparison with other figures obtained under regular conditions.

Electric Locomotives.—The Baltimore & Ohio R. R. now has in its service six electric locomotives. Nos. 1, 2 and 3, each having a total weight of 196,000 lb. carried on four pairs of driver wheels, and No. 4, a small switching locomotive, have all been in service for the past 10 years. Nos. 5-6 and 7-8, put into service about September, 1903, are specially designed freight train helping locomotives, each having a total weight in working order of 160 tons (80 tons per section), distributed over sixteen driver wheels (eight per section), with a total wheel base of 44 ft. 2¾ in., and two 14 ft. 6¾ in. rigid wheel bases. These locomotives were illustrated in this journal on Aug. 22, 1903. The driver wheels are 42 in. in diameter, each pair being geared to a 200 h.-p., 625-volt motor, with a ratio of gearing 81 to 19, providing for a total tractive effort at full working load on 8 motors of 70,000 lb., and at starting of 80,000 lb., assuming 25 per cent. tractive coefficient, giving a nominal rating of 1,600 h.-p.

The source of power is a central steam plant generating direct current at 560 volts, from which it is transmitted through feed-cables direct to the booster stations, where the voltage is increased to 625, and the current then conveyed to a storage battery which is used as a reserve and for peak loads, as well as to a surface third rail system of contact line, equipped with safety cut-out device. The locomotive motors obtain about one-half the required current direct from each the storage and booster stations The free running speed of these locomotives is about 20 miles per hour.

On level track, with good current, rail and weather conditions, Mr. Muhlfeld says, they are capable of moving a train weighing 3,000 tons with a current consumption of 2,200 amperes, which consumption, when speed increases to about 10 miles per hour, reduces to about 900 amperes. On a 1 per cent. grade these locomotives, under similar conditions, will move a train weighing 1,400 tons with a current consumption of 2,200 amperes, which consumption, when speed increases to about 10 miles per hour, reduces to about 1,600 amperes.

These locomotives handle eastbound through freight steam locomotives and trains at Baltimore, from Camden Yard to Waverly, a distance of a little over 3.4 miles, returning light. This distance includes seven curves ranging from 5 deg. to 11 deg.; seven tunnels from 400 to 7,000 ft. in length, and gradient about as follows: The first 9,000 ft. averages 1 per cent; the next, 2,000 ft. averages 1.4 per cent.; the next 2,500 ft. averages 1.5 per cent.; and the next 4,500 ft. averages 0.8 per cent.

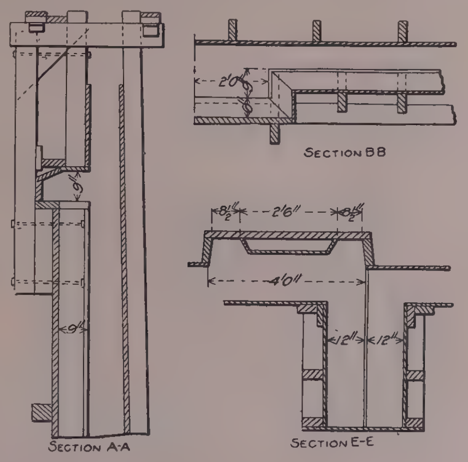
The time consumed when hauling freight trains weighing 1,395 tons in cars of various capacities and lading, 105 tons in steam locomotives and 160 tons in electric locomotive, or a total moving load of 1,660 tons, averages 23 minutes actual running time, from start until electric helper locomotive cuts from head end of train to return light.

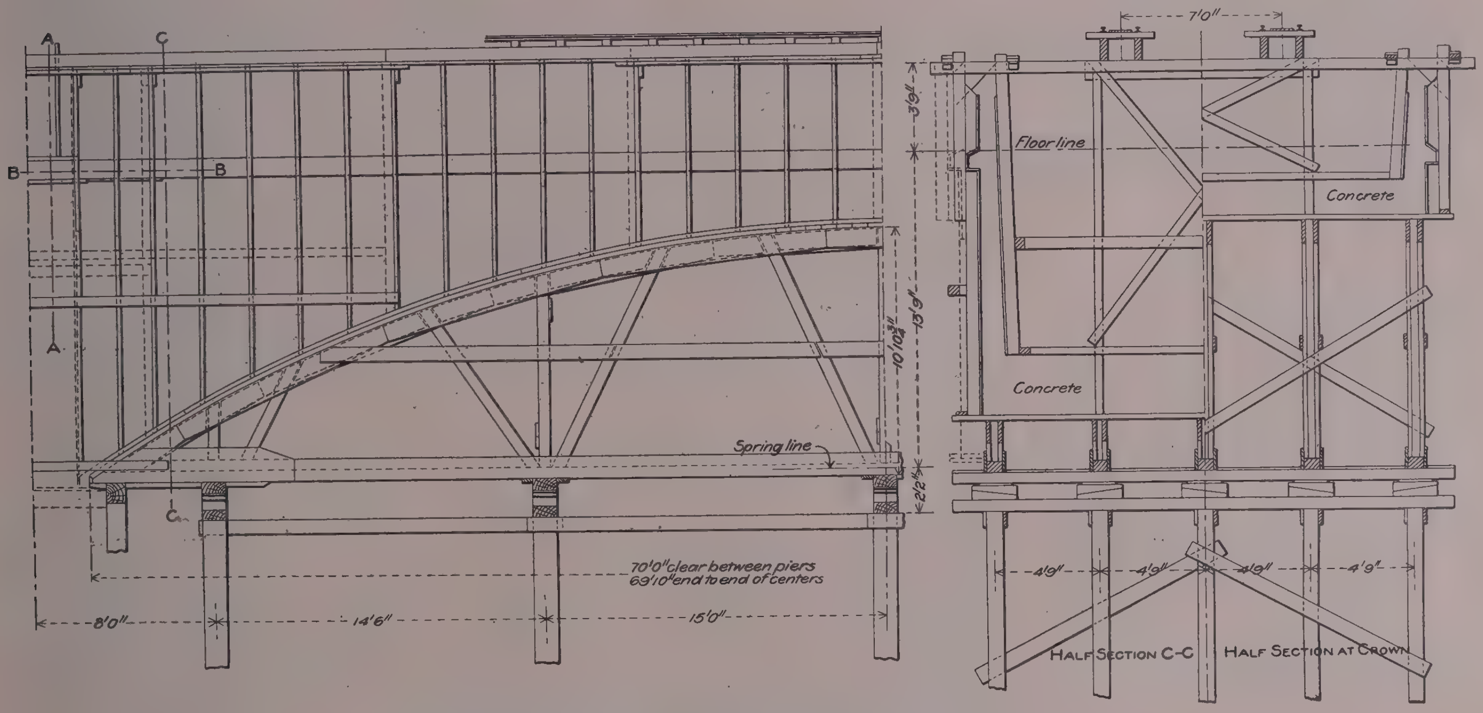
During the past one year's service the combined mileage of these two electric locomotives has been 121,015 miles, or an average of 5,042 miles per month per locomotive, computed on the basis of straight light and loaded mileage. The proportion of light and loaded mileage was half and half, about 200 miles per month per locomotive was in passenger helper service.

Considering $1.25 per net ton as a base cost for fuel delivered at the power plant, the average total operating and maintenance expenses during the year for generating the current; the labor and material for the locomotive electrical and mechanical repairs; the engineer's wages; wiping, hostlering, inspecting, oiling and dispatching; lubricating and miscellaneous supplies, was approximately $34.50 per 100 miles run per locomotive. Of this amount the average cost of labor and material applied to each locomotive for the running and shop repairs, would be $3.20 or 52 per cent. for the electrical, and $2.90 or 48 per cent. for the mechanical, making a total average cost of $6.10 per 100 miles run for both the electrical and mechanical repairs.

The above figures do not take into consideration interest, depreciation, taxes nor insurance on the investment, nor do they include the expenses incident to the maintenance of such equipment as battery, feeders, third rail, bonding wires, insulation, safety cut-out switches, extra motors, etc., which is not required for steam locomotive operation. The wages for the conductor, or second man on the locomotive, has also been omitted.

During their service considerable difficulty has been experienced, Mr. Muhlfeld says, with the shoes used for collecting the current from the surface third rail; the loosening, wear and breakage of pinions used to transmit the power from the motors to the gears on the driver wheel axles; the lubrication, heating and wear at the armature bearings; the flange and tread wear of driver wheel tires; derailments; stalling and breaking in two of freight trains due to slipping of driver wheels, more especially with wet rail or when tires of drivers connected in series are not of exact diameters, and in miscellaneous renewals and shop repairs. The driver wheel tires which





Arrangement of Centers and Molds for Spandrel Walls, Pollasky Bridge.

when new were 2⅞ in. thick, are now 1¾ in. thick, showing only 7,500 miles run per 1/16 in. metal removed at tread, and will have to be renewed within a few months.

Electric Locomotive Requirements.—From experience, to the present date, Mr. Muhlfeld suggests that an electric locomotive and its source of power, to produce the proper efficiency and economy in operation for either passenger, freight or helper service should fulfill the following essential requirements:

First.—A fire and collision resisting locomotive construction within the present clearance and weight limits; simple in design; reasonable in first cost; safe, reliable and economical for operation at varying speeds and power, and accessible for inspection, lubrication, cleaning, repairs and for replacement on track in event of derailment of any or all wheels, by the ordinary steam locomotive and car methods, without the necessity for the use of a power crane.

Second.—A locomotive that can be interchanged and operated over home and foreign tracks, which are suitable for steam locomotive or motor car equipment.

Third.—A locomotive composed of two or more interchangeable sections, each a duplicate of the other, and equipped so that each section may be operated from either end, and independently or jointly, with any number of coupled sections; the operation under any arrangement to be controlled from a single section by one engineer.

Fourth.—The elimination of pilot wheels and the concentration of the entire weight on the driver wheels, with a minimum weight per wheel at the rail of 25,000 pounds; and an arrangement of driver wheels providing for a short rigid and a long flexible wheel base, without excessive end play at axle bearings.

Fifth.—The elimination of armatures from locomotive driver wheel axles and the transmission of power to driver wheels not less than 60-inch initial diameter without the use of gearing, in a manner that will insure the economical use of current at the motors for starting and running, and eliminate the accumulation of unbalanced pressure at the wheel and rail contacts, as well as the independent revolution of one or more pairs of driver wheels when coupled in series, which occurs as the driver wheels become slightly different in diameter due to ordinary wear or material, when making transition in current at motors, or when operating on slippery track or over rails, frogs and switches of varying wear, surface, alignment and elevation.

Sixth.—The least weight between the track and locomotive frame carrying springs, to minimize the pressures, lateral thrusts and wear at the rail and wheel flanges.

Seventh.—A high center of gravity so that the vibration of the locomotive, due to the variation in surface, alignment, elevation and curvature of track can be absorbed by the weight suspended over the driver springs.

Eighth.—A proper proportion between the electrical, mechanical and dead equipment weights of the locomotive.

Ninth.—Locomotive motors compact, ventilated, cooled, protected from internal damage and mechanical injury, and of ample range of adjustment and capacity to permit of continuous operation at varying or full speed or power without excessive heating of armatures, commutators or fields above the temperature of the surrounding atmosphere. A thin, tough and elastic insulation material, unaffected by humidity or a temperature of 400 degrees Fahrenheit, and having the requisite dielectric strength.

Tenth.—A development of the maximum locomotive power for rapid acceleration and regular working, requiring no transition, as from series to multiple, in the transmission of the current to the motors, and providing for a uniform increase or decrease in tractive power to prevent irregular drawbar stresses.

Eleventh.—Suitable pumps to provide compressed air for the locomotive power brake, track sander, bell and signal operation, together with steam train heating device, and the other usual equipment.

Twelfth.—Automatic positive devices on the locomotive to insure protection in event of accidental short circuit, or disablement of the engineer.

Thirteenth.—An arrangement on the locomotive which will automatically provide for electrical braking and return to the line for the use of pulling locomotives, a considerable percentage of the energy that is generated by trains descending grades, or stopping, and which energy is ordinarily wasted in destroying material and equipment by brake shoe action on wheels or rails.

Fourteenth.—A high potential current producing, and an aerial conveying system, reasonable in first cost and economical for maintenance; the generation of the electrical energy at a central plant for the least cost per kilowatt-hour; the transmission of the lowest current over the minimum amount of metal contained in overhead contact lines, protected for weather, voltage and lightning conditions, and insuring continuous operation in event of line or equipment failure or accident; the conservative use of battery as storage for extra power that can be generated at small cost during light load and utilized to good advantage during intermittent and peak loads; the least number of transformer or convertor stations; the minimum feeder, conversion and resistance losses in current, and the elimination of electrolytic action.

General View of Pollasky Bridge during Construction.

Steam Locomotives.—Steam locomotive No. 2400, which is of the Mallet articulated duplex compound type, was designed jointly by the builders and the railroad, and was exhibited at the Louisiana Purchase Exposition. After the closing of that exposition the locomotive was brought to the Connellsville Division and put into regular service on Jan. 6, 1905.

For the purpose of increasing the capacity of an eastbound track, balancing the power on the division, and reducing the number of locomotives and crew required to handle heavy freight tonnage over a busy mountainous district, it was necessary to produce a locomotive with maximum adhesion for tractive and braking power, a minimum rail pressure per driver wheel, and a short rigid combined with a long flexible driver wheel base, to adapt it to a mountain line having considerable curvature and gradient. To accomplish this it became necessary to Americanize foreign railroad practice by making use of the Mallet articulated feature, which permits the use of a maximum effective wheel base, with a materially reduced rigid wheel base, and provides for a helper locomotive that can develop an average through freight train speed without excessive wear. The sub-dividing of the power through the use of four independent cylinder, pistons, main rods, crank pins and frames, in place of two, and the better balancing of the reciprocating parts, results in less strain on all parts, and reduces the liability for breakage and failure.

To reduce the water and fuel consumption and relieve the boiler of unnecessary punishment, the duplex Mellin system of compounding was introduced, with an arrangement of independent high and low pressure cylinder, equipped with inside admission piston and double ported flat valves, respectively, providing for a uniform and maximum tractive effort, large receiver capacity and accessibility for inspection and maintenance.

The total weight of 334,500 lb. for the engine in working order is all carried on the driver wheels, which are 57 in. in diameter. Including the tender, which has a capacity of 16 tons of coal and 7,000 gal. of water, the total weight is 479,500 lb., or about 193,500 lb. less than the combined total weight of two of the consolidation locomotives that are used for through freight service over this same mountain district.

While the draw bar pull behind the tender of two of the consolidation locomotives is about 79,400 lb., the draw bar pull of the No. 2400 is about 74,000 lb. when working compound and 84,000 lb. when working simple. The weight of train that can be taken up the mountain by two of the consolidation locomotives is about 2,025 tons contained in loaded steel cars of 100,000 lb. capacity. The weight of train that the No. 2400 and one of the consolidation locomotives can take up the grade is about 3,210 tons, contained in similar cars. The above figures are based on the locomotives operating at a speed of 10 miles per hour under fair coal and weather conditions, and with the No. 2400 working in compound gear.

The total elevation from Connellsville to Rockwood is 931 ft., the ruling grade between Confluence and Fort Hill being 1 per cent., and the total distance 43.4 miles.

The performance of this locomotive for the one year period, Jan. 6, 1905, to Jan. 5, 1906, both inclusive, was as follows:

Total locomotive mileage (computed on basis six miles per hour when locomotive is in helper service, and straight mileage allowed when locomotive is handling through freight trains), 44,976.

Miles run per ton of 2,000 lb. Run-of-Mine, 20 to 40 per cent. volatile bituminous coal used, 9.26.

Gallons of water used per 100 miles run, 15,207.

Pounds of water used per pound of coal consumed, at temperature of feed water, 5,870.

Miles run per pint of engine oil, 145.

Miles run per pint of valve oil, 200.

Miles run per pound of crank pin grease, 294.

Miles run per ton of sand used, 485.

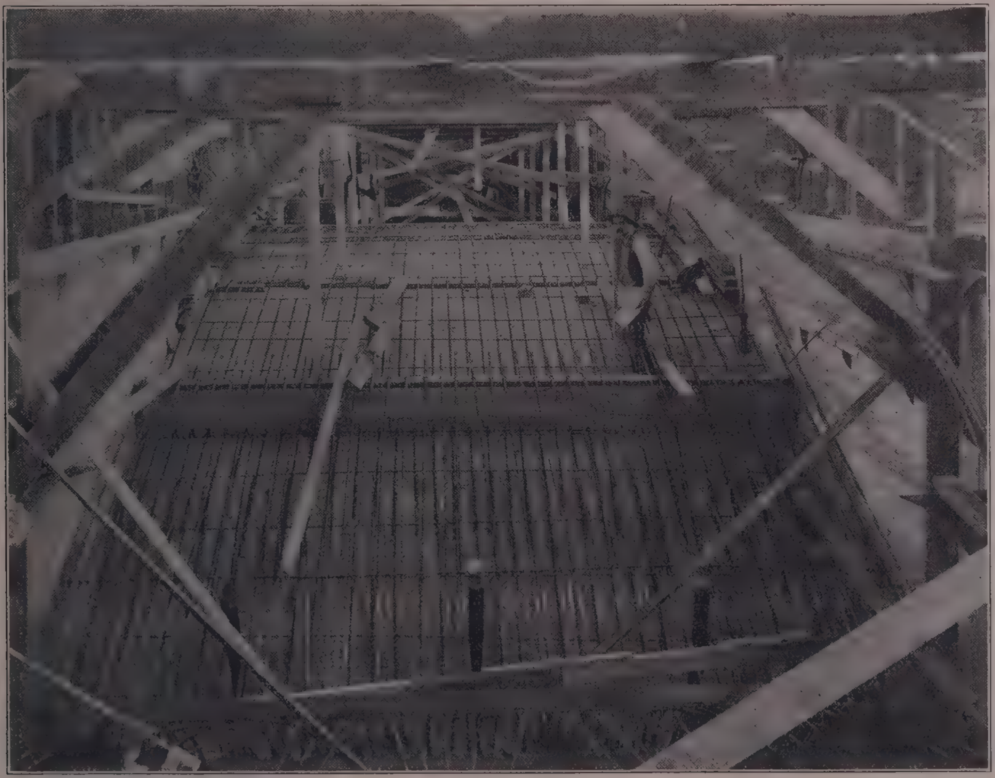
Cost for labor and material for repairs, per 100 miles run, $3.16.

The average total operating and maintenance expenses during the year for fuel, water, labor and material for the locomotive repairs, engineer's and fireman's wages, wiping, hostlering, washing boiler, inspecting and dispatching, lubrication and miscellaneous supplies, was approximately $24.50 per 100 miles run. To this figure can be added an allowance on account of general repairs and renewals to locomotive, mileage credited but not actually run, difference in cost of fuel delivered at power plant and on locomotive tender, and for the maintenance of fuel and water supply plants, and there will still be a large margin in favor of the steam as compared with electric locomotive performance, under fairly similar conditions.

During the last six months of its year's service, the locomotive was out of service 11 days, on which no mileage was made, on account of boiler washing, staybolt tests, repairs, etc., due to ordinary wear and tear, or about 6 per cent. of its time unavailable for transportation department work.

Allowing for fire-box and boiler tube renewals, heavy machinery repairs, etc., Mr. Muhlfeld estimates, from the last year's performance, that at the end of ten years the shop charges for working repairs will have averaged not to exceed 9 cents per mile run.

Method of Carrying Service Tracks over Pollasky Bridge.



Method of Placing Reinforcement in Concrete of Arch of Pollasky Bridge.

The general condition of the machinery and boiler on Jan. 6, 1906, after 12 months' service, was as follows: Treads of tire show even wear amounting to 3/16 in., or about 1/64 in. per month; tires calipered uniform in diameter. High and low pressure cylinders were in good condition, being worn smooth and not oblong or bellmouth. The high pressure piston and low pressure slide valves were in good condition. Piston valves have had the packing rings renewed once and the slide valves have received no repairs. The engine frames, splice bolts, keys, pedestal caps, braces, etc., have given no trouble, and there have been no renewals nor repairs. All driver bearings were in good condition, and while there have been two warm journals, due to lack of lubrication, since the locomotive has been in service, none of the frictional surfaces were injured. The driver boxes were in good condition, crown brasses have given no evidence of becoming loose in the boxes, and are of sufficient thickness to continue in service for twelve months before renewals need be considered. The driver wheels were fitted up when new with 1/16-in. end play between each hub and box, which has been increased to from 3/32 to 1/8 in; the front and rear driver wheels on both high and low pressure engines having the greater amount. All parts of the Walschaert gear were in good condition, and the total lost motion between the main driver wheel axles and the piston and slide valves, as measured at the valve stems, with the reverse bar in full forward position, averaged 3/64 in. for the low pressure and slightly less for the high pressure engines and for all engines in full back-up gear. The boiler, which carries a working pressure of 235 lb. indicated, was in good condition, and there has been no evidence of weakness or any trouble due to staying, leaky seams, leaky or broken staybolts or leaky rivets. The firebox was in good condition, and there has been no indication of leakage, except at the furnace door ring, where two defective rivets were replaced by countersunk head patch bolts. The boiler tubes were good for another month's service, and there was but one flue plugged which was due to its collapsing about 8 ft. from the front tube sheet.

On a railroad the principal work to be accomplished, Mr. Muhlfeld stated, is the movement of trains from one terminal to another on time, and locomotives are now expected to perform equally well work of the most varied and exacting nature. Speed limits and train loads are increasing each day, and will, no doubt, continue to do so, as the maximum expansion of car equipment and the length of trains, under favorable conditions, have not yet been reached. The first requirement by the transportation of the mechanical department is locomotives of such capacity and in such condition as will move the greatest gross tonnage that can be concentrated per foot of track space in one train at the fastest rule of speed that the track and dispatchment facilities will permit, with a proper degree of safety. How well this demand can be met in one steam locomotive of the present gauge and clearance limits by flexibility and simplicity in design, maximum proportion of adhesive to total weight, good material and construction, pure heated feed water, quickened circulation, compounding, superheating, substantial maintenance, intelligent operation, and other essentials, is a question that must be determined in the very near future; and from this determination will proceed the conclusion as to the proportions of each type of locomotive required in the motive power stock for a large modern railroad system.

Railroads are not operated to save fuel, nor to have locomotives that it does not cost much to maintain and operate, and while economy must be considered as secondary to getting trains over the line, and at the same time, the tractive power required, and the limits given within which to acquire this, make it necessary that locomotives be now so designed and constructed that more work will be produced per unit of fuel consumed; and the result should be economy.

It is a fact that electricity as a motive power is superseding steam in many cases, for the handling of suburban passenger and freight traffic, and that it may displace the latter for through passenger service, but it will be some time before electrical energy will supplant steam power for the handling of heavy tonnage for any considerable distance. While the construction and operation of electrical locomotives is still in an experimental stage, their performance during the past year, under varying weather, rail and service conditions, when compared with steam locomotives, shows a cost which will make their present use prohibitive, Mr. Muhlfeld says, when fuel must be used to generate power, except in cases of absolute necessity.

Given an electric locomotive complete and crewed, ready for operation, it would require: For terminal handling: A running repair shed with drop pit and auxiliary facilities; tracks and switches; inspection pit and sand, repair material and general stores supply. For maintenance: A general repair shop and equipment, and many expensive extra parts for quick repairs and renewals for locomotive, and plant. And for line operation: Standard gauge tracks; sand supply station; power plant building; boilers; draft arrangement; stokers, coal, water and ash intake storage and distributing appliances; coal crushers; superheaters; economizers, feed water heaters and pumps; condensor equipment; heating, fire protection, compressed air and general and detail lighting system; engines and generators; exciters; switch boards; piping, oiling system; overhead cranes and machine tools; general and auxiliary feeder and distributing systems; transformers; rotary convertors; storage battery; overhead or surface contact lines; bonding; insulation; safety cut-out device; lightning protection device, etc.

Given a steam locomotive complete and crewed, ready for operation, it would require: For terminal handling: A running repair shed with drop pit and auxiliary facilities; tracks and switches; turntable; ash pit; and coal, water, sand, repair material and general stores supply. For maintenance: A general repair shop and equipment, with a few inexpensive parts for locomotive repairs. And for line operation: Standard gauge tracks, and coal, water and sand supply stations.

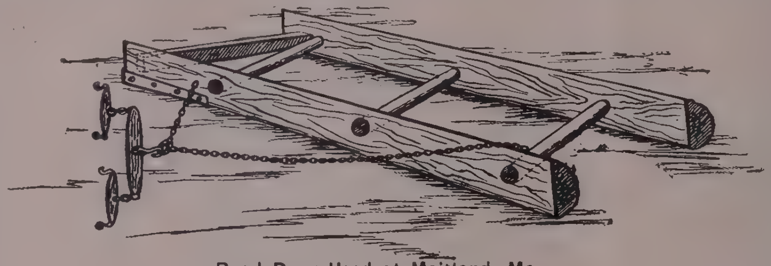
Therefore, in building a large locomotive for to-day such design and construction must be adhered to as will not only fulfill the present speed and heavy tonnage requirements, but which will remain modern for several years to come, and in the constructive features must be a combination that will insure the most conversion into energy per unit of fuel consumed, and result in the greatest efficiency and economy with respect to cost for installation, maintenance and operation. The general features for a modern locomotive may be summed as a reasonable first cost; maximum efficiency for the service, within the track, weight and clearance requirements; the greatest proportion of adhesive to total weight; a capacity to handle the heaviest gross tonnage practicable at the highest desired speed; the greatest permissible distance between coal, water or power stations; economy as regards maintenance and fuel and water consumption; a substantial construction of the least number of parts; and a capacity to perform continuous service without liability for failure.

The general requirements for electric locomotives have already been reviewed.

Track Laying Reports on the Oregon Short Line R. R.

On the Oregon Short Line R. R. it is customary to make a daily report of track-laying and for this purpose a special form has been prepared. It is a sheet measuring about 9x11 in., divided by perforations into three slips. Each slip has the same form printed on it, with lines for the main track laid to Station —— and from Station ——, feet of track laid after correcting for errors in stations, length of main track laid to date, feet and make of steel, iron, rerolled and other rails laid, west or north switch at station, east or south switch at station, length of side track laid, kind of rail used on side track, location of side track, number of frogs laid and switch stands set, number of ties per mile, weather report, delays and their cause. These forms are bound in a book. The stub slip is retained by the engineer at the front in charge of the track-laying, and when the book is filled it is returned to the chief engineer. The center slip is sent to the engineer in charge of the construction, and the third slip is sent by the first train to the chief engineer, who is also telegraphed each day the feet of main track laid. On the back of the slip sent him there is drawn a diagram of the alignment, side tracks, spurs, Y's and the like.

On grading and other work usually done by contractors a daily force report is used. This shows the number of men employed on each section or location covered by the report. A team includes two horses or mules and the driver, who is not reported among the "men," that term comprising the foremen, laborers, water boys and other men actually employed on the work. A "cart" is understood to include a horse or mule and driver, and carts and teams are separately reported. A four-horse team with two drivers is counted as two teams, and with one driver as a team and a half. This report is made in duplicate by the engineer on the work; one copy is sent to the chief engineer and the other to the engineer in charge of construction.



Road Drag Used at Maitland, Mo.

In addition to these reports each engineer in charge of a line under construction makes a weekly narrative report, describing the progress of the different works on each section and giving the percentage of the whole work of the different classes accomplished up to the date of the report. The sections are about one mile long. The details of the bridge work are not reported at stated intervals, but a record is kept in a special book of the piles driven, their penetration, and the dates of the different classes of work. The weekly reports show the progress at the different bridges and culverts in a general way only.

The chief engineer of the Oregon Short Line, Mr. William Ashton, is of the opinion that a daily or weekly report blank could be compiled that would save much labor and result in more accurate and intelligent reports than those often sent to the general office. He suggests that in the preparation of such a form, space for reporting concrete culverts, cast-iron pipe, concrete end walls and permanent work of this character should not be overlooked, as the tendency at the present time is to build more permanent structures at the outset than was formerly customary.

Good Road Work of the Chicago & Alton Railway.

The proper maintenance of country earth roads is to be widely exploited by the Chicago & Alton R. R., along its main lines in Illinois and Missouri. A special train carrying a number of engineers interested in highway work in these States will start from Chicago Feb. 12 and will be run from there to Kansas City, stops being made at several places en route to conduct meetings. The chief object of the movement is to attract the rural inhabitants to these meetings, and to familiarize them there with the best methods of maintaining the existing earth roads in the districts to be covered by the train. No field demonstrations, however, of the methods of building or maintaining earth roads will be undertaken.

So much success has been achieved by properly dragging the existing earth roads in various localities throughout the two States to be covered that much of each meeting will probably be taken up with explanations of the most efficient methods of carrying on such work. The greater part of the successful results obtained in the dragging work has evolved from work of that character that was started in the vicinity of Maitland, Mo., by Mr. D. Ward King. Mr. King will accompany the train and explain the construction of the drag used. He will also explain the methods of handling the drag and illustrate the results that are being obtained with it. A paper on the proper drainage of earth roads and the manner of obtaining adequate drainage for them will be presented at each meeting by Prof. Ira O. Baker, of the University of Illinois. Prof. Baker has been a strong advocate of the proper maintenance of the existing roads in the central Mississippi River Valley in lieu of an attempt to construct permanent earth roads until the results to be obtained by such construction will justify the expenditure required. This same sentiment also quite generally exists among most of the people in the districts which will be visited. Mr. A. N. Johnson, State highway engineer of Illinois; Mr. Joseph R. Falkerson, a member of the Illinois State Highway Commission, the dean of the College of Agriculture at the University of Illinois, and several others will accompany the train and speak on pertinent subjects at the meetings.

The train will stop an entire day at twelve different places and the railroad company will make excursion rates within a radius of 50 miles of each stopping point. One meeting will be held each day and the remainder of the time devoted to personal work among those in attendance. The stopping places will be towns of 500 to 5,000 inhabitants in order that the largest number of people from the country in the immediate vicinity may be reached. The entire expense of the meetings, including advertisements and the operation of the train, is to be provided for by the railroad company. Road construction and maintenance is a serious problem in the territory to be covered and it will be interesting to note the results of an attempt to give an impetus to an educational movement among those most closely interested and from whom co-operation must be secured if good roads are to be obtained.

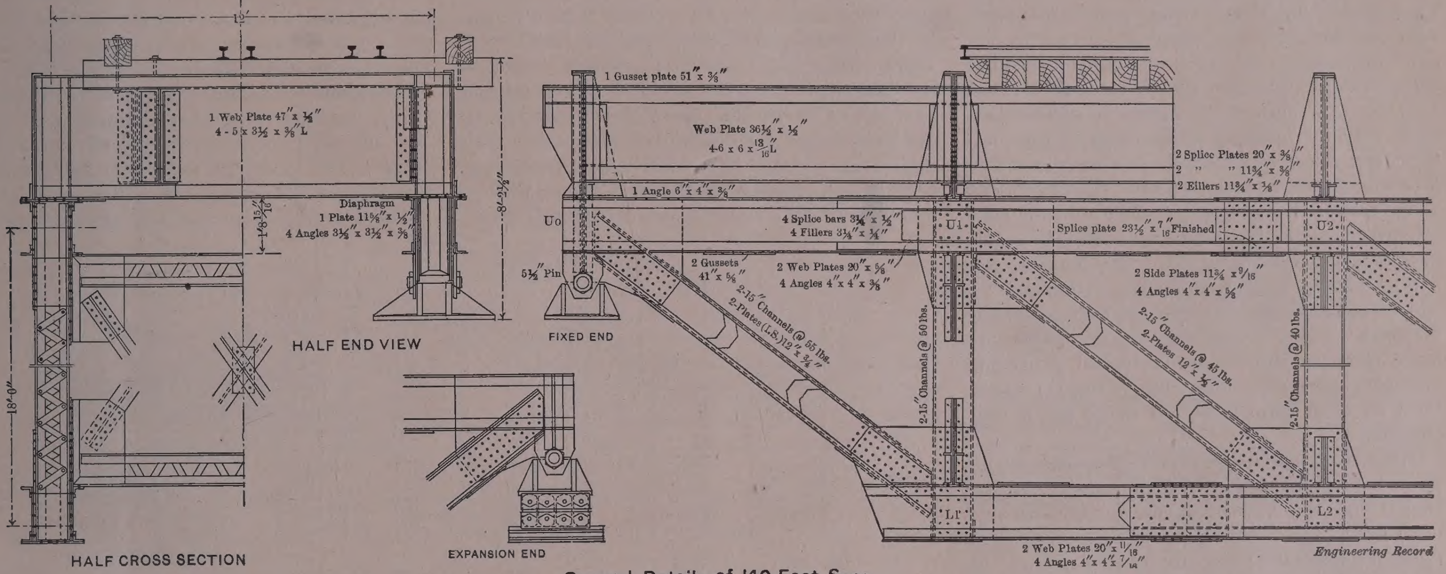
The construction of the drag which has been used with so much success in maintaining earth roads in parts of Missouri and Illinois is well shown in the accompanying illustration. The drag is exceedingly simple and can be built in the workshop on any farm. It consists of the halves of a 12-in. log 7 to 9 ft. long, depending on the size of the team, which are placed as shown. Instead of the log slabs 2x12-in. plank can be used, but each plank ought to be reinforced by a longitudinal 2x4-in. piece at the middle. The cross sticks are set to hold the half logs 30 in. apart and a platform of 1-in. boards is laid on the sticks. A hitching ring for a doubletree is placed 2 to 2.5 ft. in front of the drag with chains. After each rain the drag is driven up one side of the wheel track in the road and back on the other side to throw the earth to the center. In order to accomplish this best the chains are made of such length that the drag sets at an angle of 45° to line of the road. The usual custom has been for each man to drag the road along his property, but some more dependable method than that will probably be suggested.

Reconstruction of the Bismarck Bridge.

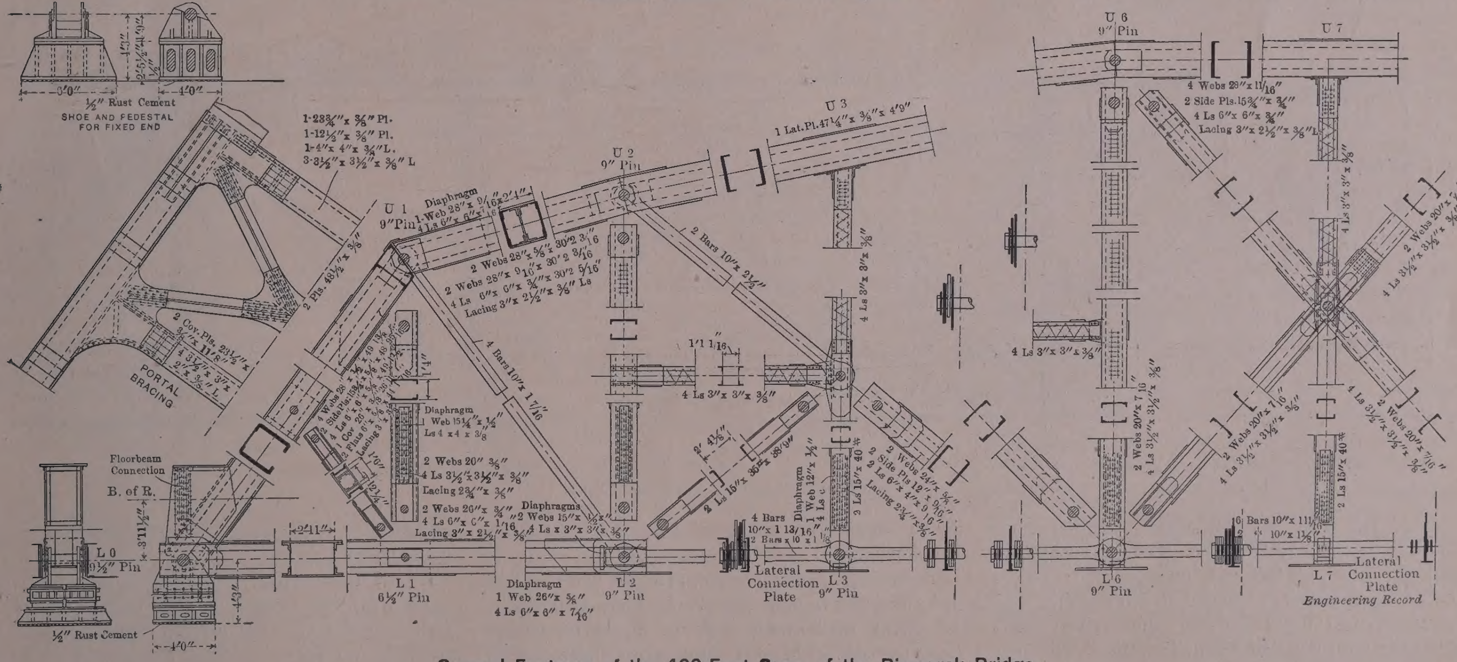
The Bismarck Bridge carries a single track of the Northern Pacific Railway over the Missouri River just west of Bismarck, North Dakota. It has a total length of about 1,470 ft. and a clear height of 50 ft. above the mean water level. It crosses the river where the latter has a maximum depth of about 40 ft. and is supported on granite piers with foundations carried down by pneumatic caissons to footings in solid rock about 70 ft. below water level. The original structure was designed by the late George S. Morison and was built by the Detroit Bridge & Iron Works, and erected in 1882. It was proportioned for a live load of two 75-ton engines followed by a 2,000-lb. train load, and had three 400-ft. double intersection through truss pin-connected channel spans with one 113-ft. deck approach span at each end.

It was notable as being one of the earliest Missouri River railroad bridges: that it was one of the first steel bridges: and on account of the method of erection. The bottom of the Missouri River at this point is very unstable, the river is subject to violent floods, and sudden changes in the channel occur. It was therefore believed when the bridge was built that ordinary falsework for it could not be maintained. In order to diminish as much as possible the constriction of the channel two temporary intermediate pile tower piers were built between the masonry piers of each span and three Howe truss falsework spans, each of about 130 ft., were built on shore falsework and launched from it to the tops of the towers on scows, towed to position and seated on the tops of the temporary piers by scuttling the scows. In this way a solid platform above flood level was provided on which the permanent spans were erected in the ordinary manner. After the erection of the first span its falsework trusses were removed by the scows to corresponding positions in the second span and so on, thus erecting the three main spans with one set of falsework trusses. This method of erection had at that time few if any precedents and was considered a daring and brilliant achievement which has since been frequently copied with various modifications.

As the masonry piers are in good condition it was decided to use them for the new structure, changing them as was found necessary for the new bearings. The main spans are accordingly of the same length and width as before, but are of different height, and one approach span is increased to 140 ft. on centers on account of the tendency developed by the bank to slip towards the river, a condition which caused the displacement of the river pier and required its repairs as described by this journal several years ago. The new superstructure is calculated for the Northern



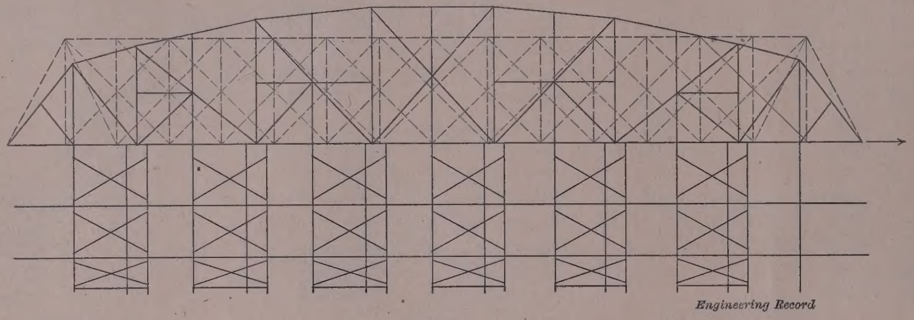
General Details of 140-Foot Span.



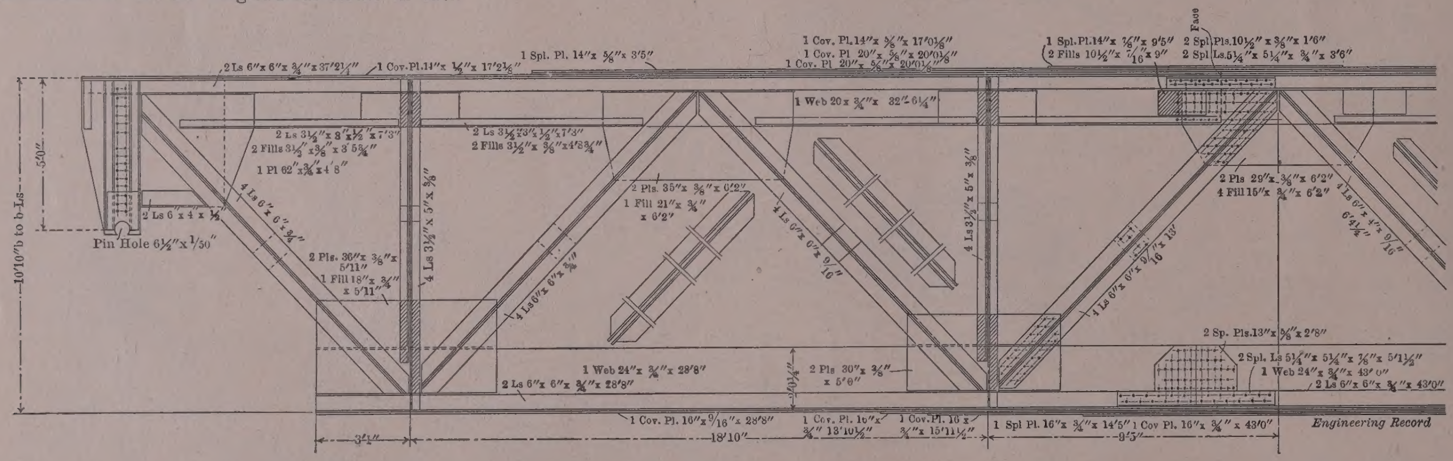
General Features of the 400-Foot Span of the Bismarck Bridge.

Pacific Railway Co.'s standard loads of two 188½-ton locomotives, followed by a 5,000-lb. train load.

The main span trusses are 22 ft. apart on centers and have inclined top chords from 39 ft. high at the hips to 65 ft. in the center. They are divided into fourteen 28-ft. 7-in. sub-panels with four sub-diagonal struts and two end post struts in each truss. The trusses are connected by X-bracing in the planes of the top and botom chords, by heavy portals in the planes of the end posts, and by deep sway bracing in the planes of the intermediate vertical posts which leave a clearance of 22½ ft. above the rails. The portal is made with top and bottom horizontal struts connected by X-braces, as indicated in the half elevation. The top strut has a trapezoidal cross-section made with two bent and two square flange angles and two cover plates. The bottom strut is similar except that it has a rectangular cross-section. The X-brace diagonals have I-shape cross-sections made with two pairs of angles back to back latticed, and are mitred at their intersections where they are spliced together between a pair of large flange plates. Both struts are spliced at the ends by cover plates connecting them with the wide gusset plates which project from the top and bottom flanges of the end posts, forming jaws, which receive the field-riveted connections for the diagonals. The intermediate sway braces are made with top and bottom horizontal struts and multiple intersection diagonals riveted between them so as to form a sort of lattice girder construction.



Relative Design of Old and New Trusses, 400-Foot Span.



General Design of 113-Foot Span.

The trusses are divided into sub-panels by intermediate vertical posts which support the top chords and serve as suspenders for the intermediate floor beams. The top chord connections of these intermediate posts are riveted as are the connections of the six longitudinal struts in each truss to the main vertical posts, all other truss connections are pin-connected. The top chords are made in full panel lengths except at U 1-U 2 and adjacent pieces are joined on pin centers. The center vertical posts and the sub-vertical posts are made with pairs of channels latticed, all other compression members are made with built channels and all except in the lower chord have their flanges turned inwards and latticed, the only members which have full-length cover plates being the inclined end posts. The end panels of bottom chords are stiff members made with a pair of channels with their flanges turned outwards and latticed. At the feet of the ends posts the web plates are extended by a pair of gusset plates shop-riveted to them to form jaws connected by a transverse vertical diaphragm and affording connection for the end floor beam in the plane of the end pins.

The end lower chord pins engage the two webs of cast-steel shoes which at the fixed end are seated on cast-steel pedestals 2 ft. 5½ in. high. At the expansion end they are seated on nests of seven segmental cast-steel rollers having had plates made with track rails planed to a height of 4¾ in. and riveted to a 1-in. bed plate. The bearing rails have their flanges beveled in the ordinary manner so that there is little clearance between their heads. A special longitudinal bearing is provided on the center line to engage the groove in the rollers. The bed plate is bolted to a cast-steel bolster 11¾ in. high. This bolster and pedestal at the fixed end are anchored to the masonry and are seated on it with rust cement joints ½ in. thick.

The 140-ft. deck span has a pair of riveted trusses 18 ft. deep on centers with all the members field-riveted together. The top and bottom chords are made with built channels latticed and in the middle panels their webs are reinforced. Pairs of wide ⅝-in. gusset plates are riveted to the insides of the webs at panel points, making jaws which receive the vertical and inclined posts, the latter being made with pairs of channels with their flanges turned in and latticed. The inclined posts have their webs reinforced at the ends where there are spliced plates shop riveted to fillers so as to form jaws engaging the gusset plates at panel points.

The trusses are connected, at panel points 2 and 3, by top and bottom transverse T-shape horizontal struts made with pairs of 6 x 4-in. angles back to back. Between these struts there are X-braces made with single 3½x3½-in. angles riveted at the ends of vertical web plates, which receive the transverse struts and field riveted to the vertical posts of the truss. At *U* 1, the transverse bracing is heavier as indicated in the half cross-section. The top and bottom lateral systems have diagonals made with pairs of angles riveted together back to back and are field-riveted at their ends to connection plates on the top flanges of the chords at intersections, one diagonal is continuous and the other is cut to clear it and spliced by a horizontal flange plate riveted to both diagonals. In the center panels the diagonals are single 5 x 3½-in. angles.

The floor beams are seated across the top chords and are knee-braced to them by solid web plates field riveted to the outer flanges. The stringers are eccentric on account of a spiral curve, which is necessary in the track of this span. The gusset plates at the ends of the top chords are connected by vertical transverse diaphragms in the planes of the end floor beams and receive bearing pins which engage cast-steel pedestals, affording them full-length half-hole bearings. At the fixed end these pedestals are seated directly on the masonry and at the expansion and they are seated on nests of four segmental rollers with rail bed plates.

The 113-ft. approach span has also riveted deck trusses which differ materially with those of the 140-ft. span, the principal features being in the cross-sections of the members. The top chord has an I-shape cross-section with large continuous top flange angles. The bottom flange angles are much smaller than the top flange angles and are not continuous, being made in short sections cut to clear the vertical and diagonal posts which continue across the top chord web to the upper flange. The top chord is made in three sections field-riveted at splices. The bottom chord has a T-shape cross section and is also made in three lengths field riveted together with web and flange angle cover splices.

All of the vertical and inclined members are made with four angles riveted together back to back in pairs so as to engage opposite sides of the web and gusset plates. The gusset plates at the ends of the top chords are extended beyond the inclined members and are reinforced by double pairs of vertical angles which virtually form short vertical posts and stiffen the plates to transmit the load to the end-bearing pins. The trusses are connected by light transverse sway frames connected to the vertical posts and by heavier transverse bracing in the planes of the end-bearing pins. The top and bottom lateral systems consist of zigzag diagonals made with single and double angles. The trusses are spaced 6 ft. apart in the clear and carry the track ties directly on the top chords without floor beams or stringers.

As it was necessary during construction to maintain uninterruptedly the unusual heavy traffic occasioned by the Lewis & Clarke Exposition at Portland, Oregon, it was decided to erect the new superstructure on pile falsework and to execute the work by the railway company's force, which it was believed could remove the old structure and assemble the new with less probability of delay or interruption to traffic than if the work was done by a contractor. The erection force was organized and preliminary preparations were made so that when the high water stage in the river at this point was past, about July 10, everything was ready to increase the force and prosecute the work vigorously until its successful completion, which was accomplished December 25, 1905.

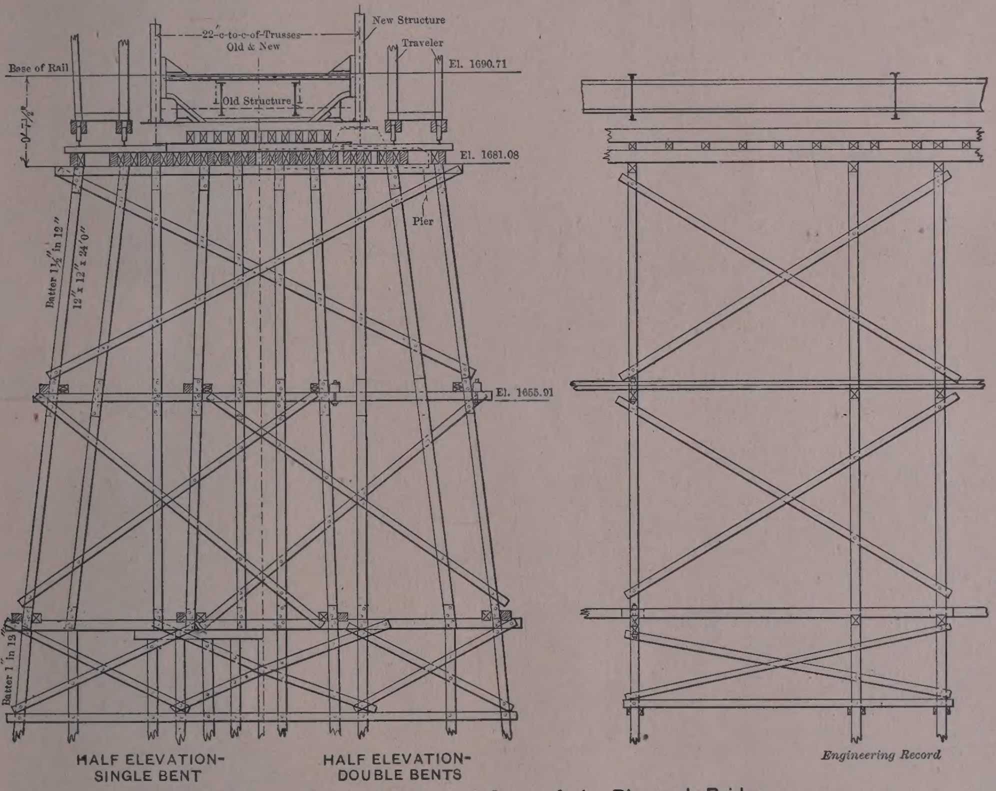
Under the main spans piles were driven and falsework bents erected on them to form six independent towers for each span connected by horizontal longitudinal pieces in two planes as indicated by the general diagram. Each tower consisted of three bents, one bent in the plane of the sub-vertical posts and the other two bents 4½ ft. each side of the main panel point. The pile and trestle caps and the plumb and batter posts were all made of 12 x 12-in. timber, the latter being spliced across the former with single 4 x 12-in. wooden scabs 4 ft. long, having six ⅞-in. bolts. The diagonal braces were single 4 x 10-in. pieces and the horizontal struts at the water each were pairs of 4 x 10-in. and 6 x 12-in. pieces.

The four lines of 12 x 12-in. upper longitudinal struts connecting the towers were made with double 6 x 12-in. pieces in 36-ft. and 26-ft. lengths, breaking joints so as to form continuous members. The four lower longitudinal struts were single 12 x 12-in. pieces overlapping at the pile caps on which they were dapped 1½ in. The trestle caps supported 34 lines of 9 x 18-in. stringers lapping at the supports and arranged as shown in two tiers with 10 x 10-in. transverse distributing timbers 4 ft. apart between them. The upper tier of stringers received the track, which was blocked up from them while the old structure indicated in the diagram by dotted lines, was removed. There were required 633 cedar or fir piles from 15 to 60 ft. in length, most of them in the latter dimension. All other falsework timber was of Oregon fir.

The old superstructure was removed and the new one was erected by an ordinary gantry tower traveler, with vertical and horizontal clearances of about 70½ ft. and 28 ft. respectively. It was made with three bents spaced 30 ft. apart and connected by top and bottom caps and sills and by two intermediate lines of 8 x 10-in. horizontal timbers. One panel was also X-braced between the horizontal struts with single 1-in. screw rods passing through the vertical posts and having cast-iron angle blocks for their nut bearings. Each bent was made with two plumb posts and two batter posts. Each set being separated about 4½ ft. at the botom and 10 ft. at the top and braced together with pairs of horizontal struts from 7 to 10 ft. apart. Each panel between these struts was X-braced with a single 2 x 10-in. diagonal plank on each side secured with the same bolt that connected the 2 x 10-in. horizontal pieces.

Under the foot of each plumb post and batter post there was a double sill made with two 8 x 10-in. timbers 62 ft. long, between which the feet of the posts were mortised and bolted and between which were journaled three single-flange wheels, making 12 in all for the traveler. At the top of each bent there was a transverse truss 10 ft. deep over all, made with a pair of 8 x 16-in. timbers 52 ft. long for the top chord and a pair of 4 x 12-in. timbers 50 ft. long for the bottom chord. The upper chords of these trusses supported two pairs of 9 x 18-in. jigger beams, one pair in the plane of each bridge truss.

The 400-ft. spans were erected in position and swung while under traffic, but the approach spans were assembled on falsework alongside the old structure, where they were riveted up complete and between trains they were moved transversely into their permanent position. The entire work of removing the old and replacing it by the new superstructure was accomplished without accident, and without materially interfering with traffic. The work was done under the general direction of Mr. E. J. Pearson, chief engineer, of the Northern Pacific Railway Co., and Mr. Ralph Modjeski, consulting engineer, who designed the new structure, organized the force in the field and had direct charge of the work. Mr. Ernest Nickerson was resident engineer at Bismarck, and Mr. J. Saguin was superintendent of erection. The American Bridge Company, of New York, Mr. Paul L. Wolfel, chief engineer, was the contractor for the manufacture of the superstructure, which was built at the Ambridge plant, excepting the track stringers, which were manufactured at the Detroit plant.



Falsework for the 400-Foot Span of the Bismarck Bridge.

Book Notes.

Engineers who wish to become acquainted with what has been accomplished in Germany in the way of electrical power transmission cannot do better than to read Mr. Wilhelm Philippi's "Elektrische Kraftübertragung," a well-illustrated book of 386 pages. It is written by an engineer for engineers, and covers both direct and alternating current plants. Formulas are given for many of the important features of such equipments, and the application of electricity to hoisting, elevators, cranes, machine tools, ventilating fans and general factory and farm purposes is discussed. The book seems to be particularly suited for readers acquainted with the general principles of generators and wishing to acquire a broad view of what electricity is used for outside of lighting; it should be pointed out, however, that all the transmission systems described are short ones, in comparison with some in the United States. (Leipzig, S. Hirzel, 18 marks.)

One of the most interesting books on the production of gas is the "Short Treatise on the Destructive Distilation of Bituminous Coal," published in a very handsome style by the United Coke & Gas Co. of New York. The nature of coal, its destructive distillation and the types of apparatus used for the purpose are first taken up. Then follows a section on the bee-hive oven, tracing its development, describing its operation and pointing out some of its disadvantages. The coal gas retort is next taken up in the same way, and the consequence of making gas the chief product of the destructive distillation is discussed. The by-product coke oven is next explained in considerable detail, both historical and constructional, particularly the Otto Coppée, Otto-Hoffmann, Otto Hilgenstock and United-Otto types. This chapter is closed with a discussion of coke quenching and a description of the Moore coke quencher. The general subject of gas is next taken up, wtih special reference to coke production, condensation, condensing apparatus and ammonia plant. This is followed by short chapters on the recovery of benzol and the preparation of coal for coking. The succeeding chapter on products is a very comprehensive one and contains an interesting explanation of the uses of the products of these ovens. Finally there are some excellent illustrations of by-product oven installations. While the book is primarily a trade publication, it is so well written and elaborately printed and illustrated that it deserves recognition among the engineering books of the day.

A considerable number of people have expressed a desire for a small book explaining the method of installing small telephone systems and free from the elaborate descriptions of the apparatus and its fundamental principles which are found in the excellent manuals of Mr. Miller and Mr. Abbott. Such a handbook is Mr. James F. Fairman's "Standard Telephone Wiring," a little leather-covered manual of 100 pages. It is an explanation of the methods of putting in circuits for straight lines, party lines, private lines and intercommunicating systems, with a brief description of the apparatus used and the rules of the fire underwriters concerning such wiring. It is only within a few years that the value of telephones in large offices and manufacturing establishments has been fully recognized. At first the experience gained by a wholesale introduction of desk instruments connected with the city lines was very unsatisfactory. Clerks and office boys used the wires for talking with acquaintances in other establishments and the women in particular made the telephones a nuisance. With the introduction of independent intermediate systems, so that only heads of departments have city connections while the remaining instruments can only be used for talking about the office or the works, this trouble has been practically stopped. Probably a good many offices would install these intercommunicating systems if their simplicity were appreciated, and this little book will be found an excellent one to turn to for the kind of information that a busy man wishes. (New York, McGraw Publishing Co., $1.00.)

A good description of the present condition of gas works engineering in Great Britain is given in Mr. C. E. Brackenbury's "British Progress in Gas Works Plant and Machinery." Starting with the methods of handling coal at small and large works he explains the kind of equipment employed, dwelling mainly on what may be called the standard types of to-day but giving enough notes on older forms to enable the reader to form some idea of the progress made. The book is particularly interesting to an engineer who knows American methods and equipment in gas works but is not familiar with foreign practice, which differs considerably from ours, particularly in the use of inclined retorts. The book will also be useful to any reader who desires general information concerning the processes employed in making gas, for the author outlines his subject in a logical and clear manner, as the following order of topics will show: coal receiving, coal storing, retort houses and benches, retort-stoking machinery, inclined retorts, coke plants, condensers, exhausters, washer-scrubbers, purifiers, station meters, gasholders, station governors, water gas plant, gas appliance, by-products and a bibliography of books on the subject. The volume is profusely illustrated and has a tasteful appearance rare in engineering books. (Chicago, W. T. Keener & Co., $2.40.)

THE WIRING HANDBOOK. By Cecil P. Poole. New York, McGraw Publishing Co., leather, 8x4½ in., 85 pp., $1.00.

About six years ago the author of this book brought out a somewhat similar one entitled "Electric Wiring," which had a deservedly large use. In the time that has elapsed since its publication, there have been a number of changes introduced into wiring practice, and a greater variety of problems have arisen. Moreover, the author's experience as the editor of the "American Electrician" brought to his attention many special wiring problems arising in all kinds of plants and in many parts of the country. For this reason it has become desirable to bring out an entirely new book, embodying all the data that an engineer or architect will need in laying out the wiring for lighting and power in buildings. The value of the book is two-fold, the explanations of the methods of running wires for different purposes, and the large number of tables to render calculations essentially unnecessary in determining answers to the arithmetical problems that arise in such work. There are thirty-two of these tables, and any wireman will find them worth many times the cost of the book.

The book opens with an explanation of wiring terms and the measurement of feeders and mains. The different methods of wiring a floor are illustrated and the general character of the calculations for determining the sizes of the wires is explained. The next section takes up in more detail the determination of wire sizes and explains with the assistance of numerous examples the various steps to be taken in calculating the sizes of all wires. Three-wire circuits are then taken up, and the special methods to be followed with such installations are described. A short section on direct-current motor wiring is next given, after which the wiring for alternating currents is discussed in a clear manner which should remove many of the perplexities that wiremen find in this class of work. This completes the discussion on wiring proper, but there are further chapters on the determination of the size of bus-bar conductors and on the connection of the various instruments used on the switchboard or in the circuit. The book closes with a digest of the underwriters' rules for wiring.

The book is a good example of what such manuals should be. It contains elementary information which engineers will find needless and there are some formulas which a wireman will not understand. It is difficult to prepare such a book without this characteristic, unless accuracy is sacrificed in the portions relating to alternating current work, or the usefulness of the book to wiremen is destroyed by writing only for technically educated engineers. Fortunately the author has been led aside neither by a desire for lofty engineering reputation or for so-called popularity and has accordingly produced a book that is worth owning, whether by the engineer or the wireman.

Letters to the Editor.

CURVED STREET LINES.

SIR: I do not know why Mr. Spofford should say, as he does in yours of Feb. 3, that a curve cannot be located on the ground. It is true, of course, in one sense, that points set by running a series of chords do not give a curve, but it is equally true that a number of stakes set in a row do not give a straight line. As a matter of practice, both straight lines and curves can be staked out as closely as any class of mechanics' work requires, and that is the main thing. If a highway line be correctly staked out, a sufficient number of bounds or reference marks provided, and a correct record made of the whole, it may be full of curves, if that is desirable, and still be correctly reproduced, but of course, you must have the right kind of men to do it. Aldermen and County Commissioners need not know anything about geometry, but they should have wit enough to entrust such matters to skilled surveyors.

The desirability of curves for other reasons, however, may well be questioned. Curves are pleasing to the eye, but the effect produced by a series of chords to a curve of long radius is also pleasing if the chords are not too long.

Short radius curves are well enough for fences, walls, etc., but few men like to plan business blocks on curved lines, and almost everybody wants to occupy all the land he owns, in a city. So, recognizing the undoubted need of some kind of cut-off lines to avoid the awkwardness of two streams of people meeting at right angles, it is probably better, as a rule, in cities, to adopt cut-off lines making angles of about 45 deg. with lines of intersecting streets.

T. P. PERKINS.

Lynn, Mass., Feb. 15.

SETTING GRADE STAKES.

SIR: To settle a friendly but more or less important discussion between two young civil engineers will you not give space in the Record to say whether or not it is customary and important to check "grade stakes" on railroad location before construction is commenced? By "grade stakes" I mean those indicating where cutting ends and filling begins and vice versa. Should not all calculations and measurements pertaining to any structure, of importance, be checked before construction is begun?

Yours truly, A. C. BARROW.

Yamacraw, Ky., Feb. 5.

[This inquiry was referred to Mr. H. A. Stahl, office engineer, New York Central & Hudson River R. R., who has furnished the following statement by Mr. C. J. Parker, of that company: "As to checking side stakes, as a rule, before side staking is started, careful levels are run over the center line stakes, and existing bench marks carefully checked before construction begins. Side stakes are then set by the level party from elevations taken from the established bench marks, and a check made on the nearest center stake. In other words, the party doing the work is supposed to check itself as it proceeds. It is customary and important that all calculations and measurements pertaining to any structure of importance be checked, before construction begins." Comments on this subject explaining any different practice on other roads will doubtless be of interest to many readers of this journal.]

CIVIL SERVICE EXAMINATIONS IN NEW YORK CITY.

SIR: I was much interested in the letter in The Engineering Record of Feb. 3 giving the questions recently set in the civil service examinations for positions on the engineering staff of the Board of Water Supply of this city. My own experience in a recent examination for the position of assistant engineer for the Rapid Transit Commission, a position paying $1,200 per annum, convinces me that the men who took the Water Supply examination had nothing to complain of. The questions set them were fair and comprehensive. On the other hand, some of the questions set for the Rapid Transit examination were certainly not calculated to bring out information of much value in determining the candidates' fitness for the work to be done.

This may be shown by mentioning some questions set in arithmetic, which had to be answered in a short time. One problem was to extract the cube roots of 58704 and 0.002896. These figures may not be exactly correct, but they indicate about what was wanted. A second problem was to find the height of a building if a line of sight to the top from a point 120 ft. from it makes an angle of 60 deg. 30 min. with the horizontal. In addition to such problems, depending for their solution on a good memory solely, there were a number of a tricky nature, in which the data were stated in a manner never used in engineering practice and likely to mislead an engineer working hurriedly to get through a long examination in a short time. While I will acknowledge that there was nothing in the paper that an engineer having access to mathematical tables should not be able to perform, it seems to me that trick questions, or those involving a recollection of the methods of extracting cube roots, or those requiring a knowledge of the tangent of an angle of 60 deg. 30 min. are not what civil service examiners should set.

Yours truly, CANDIDATE.

New York, Feb. 14th.

THIRTEEN THOUSAND THERMOMETERS were tested last year by the Bureau of Standards at Washington, the work being based on the international hydrogen scale of temperature. They have shown that a large percentage of the high-temperature and industrial thermometers were subject to very considerable changes with use, due to improper methods of treatment during manufacture. A study has also been made of instruments for very high temperature observations and a number of pyrometers have been calibrated for private parties to use as standards.